

Transient hygro-thermal analysis during concrete hardening: concrete slab

Analysis of cracking during hardening is often studied by only studying stresses due to effect of thermal expansion (warming) and contraction (cooling).

The short-term effect of creep and shrinkage is not always considered but will be handled in a separate example.

In this example, the temperature variation is determined according to the principal workflow below:

1. Generate static 3D model using volume elements.
2. Define thermal nonlinear transient material properties of concrete.
3. Define structural material properties of concrete (not performed in example).
4. Define thermal transient boundary conditions.
5. Define structural boundary conditions (not performed in example).
6. Define thermal transient loads.
7. Perform transient thermal analysis to determine temperature.
8. Perform transient structural analysis to determine stress, crack risk and crack width (not performed in example).

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1. Input Receipt 2. Results			

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1. GENERAL / MEASUREMENT

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	Part A – CALCULATION ASSUMPTIONS	Status :	Page: A1:2
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1.1 CONSTRUCTION TYPE

A concrete base slab is cast against soil.

1.2 TIME PERIOD

The risk of cracking is studied over a time period of 30 days.

1.3 REMOVAL OF FORMWORK

Form work (plywood) s removed after 3 days.

1.4 AIR TEMPERATURE

Outside air (T_{air}) : +20° C

1.5 CONCRETE

Concrete : C35/45

Water/cementious ratio (v_{ctekv}) : 0.45

Cementhalt: 390 kg/m³

Type : II (LH)

Casting temperature: +15° C

Casting speed: max. 1 m/h

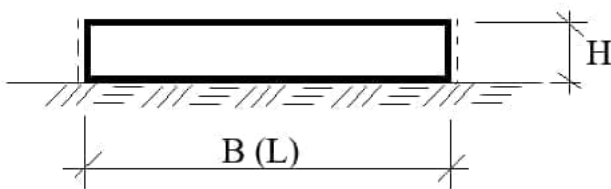
	Part A – CALCULATION ASSUMPTIONS	Status :	Page: A1:3
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1.6 CONCRETE NONLINEAR MODELL

When studying risk of cracking and occurring crack width the concrete nonlinear model CEB-FIP modell 109 is used. This material model takes into account the effects of heat of hydration, creep and shrinkage, along when deteminating transient evolution of properties $E_c(t)$, $f_{cc}(t)$ and $f_{ct}(t)$.

1.7 MEASUREMENTS

Bottom slab: $B \times L \times H = 20 \text{ m} \times 40 \text{ m} \times 3 \text{ m}$



	Part A – CALCULATION ASSUMPTIONS Transient hygro-thermal analysis during concrete hardening: concrete slab	Status :	Page: A2:1
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2. SYSTEM ANALYSIS

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2.3	MATERIAL	page 2:4
2.4	BOUNDARY CONDITIONS	page 2:5
2.5	MESH	page 2:6

	Part A – CALCULATION ASSUMPTIONS Transient hygro-thermal analysis during concrete hardening: concrete slab	Status :	Page: A2:2
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2.1 GENERAL

The concrete slab is modelled only as one quarter due to symmetry.

The slab is modelled in 3D using *volume element* (HF20) vid nodes in vertical direction at distance 0.15 m and at distance 2.0 m in horizontal plan.

No structural constraints are considered in this modell since both formwork and soil are considered soft, this all outer surfaces of slab are modelled as *thermal broundry conditions* that are free.

Changing enviroment at outer surfaces of slab are modelled used transient *thermal loading*.

Two analysis are performed constant ambient air temperature (Analysis 1) and varying ambient air temperature (Analysis 2).

Analysis 1: constant air temperature $T_{\text{air}} = +20^{\circ} \text{C}$.

Analysis 2: cyclic varying air temperature over day $T_{\text{air}} = +10^{\circ} \text{C} \rightarrow +30^{\circ} \text{C}$ with mean daily temperature $T_{\text{air}} = +20^{\circ} \text{C}$.

Appendices:

Appendix	Name
1	Input receipt
2	Results

	Part A – CALCULATION ASSUMPTIONS Transient hygro-thermal analysis during concrete hardening: concrete slab	Status :	Page: A2:3
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2.2 SKETCH SYSTEM ANALYSIS

The single VOLUME is described by SURFACES (S1-S6).

SURFACES are described by LINES (L1-L12).

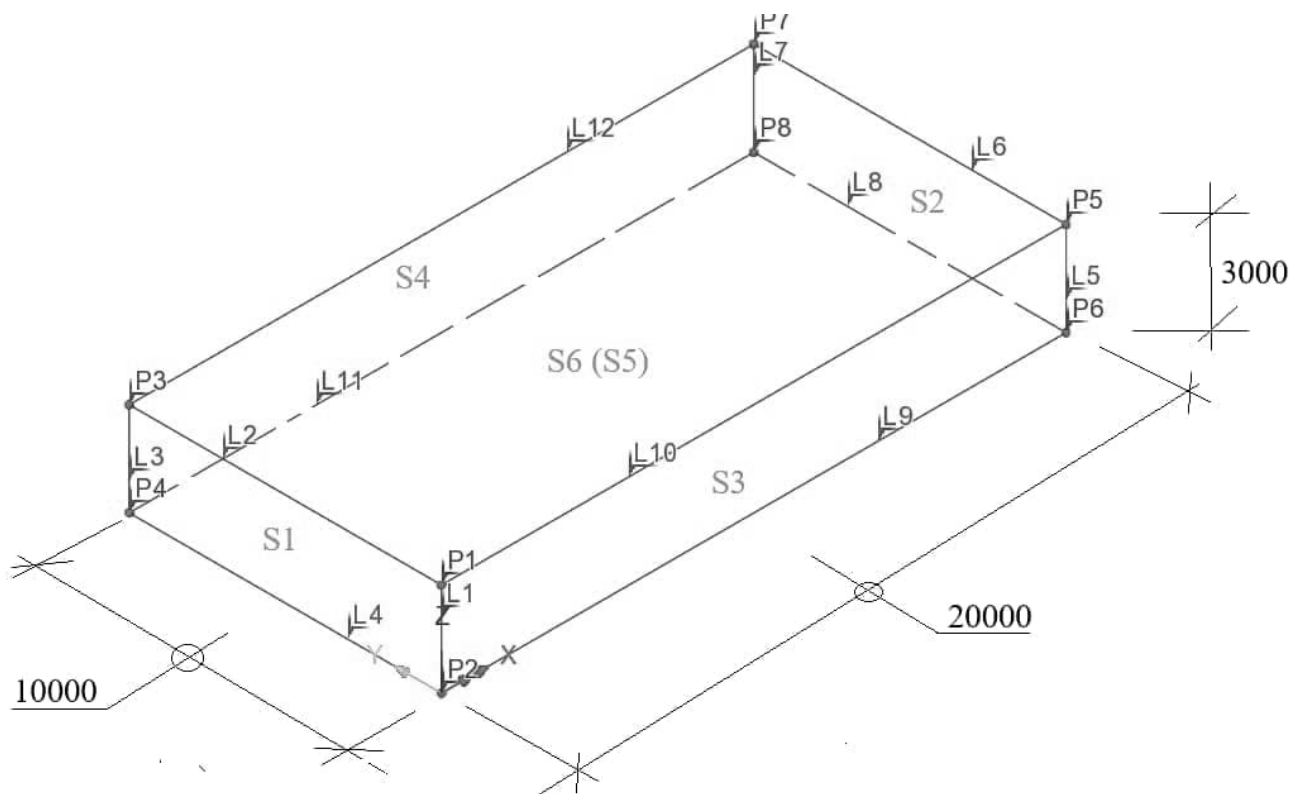
LINES are described by POINTS (P1-P8).

All coordinates needed to describe POINTS are found in appendix 1.

All POINTS needed to describe LINES are found in appendix 1.

All LINES needed to describe SURFACE are found in appendix 1.

All SURFACES needed to describe the VOLUME are found in appendix 1.



Overview 3D Geometry

	Part A – CALCULATION ASSUMPTIONS Transient hygro-thermal analysis during concrete hardening: concrete slab	Status :	Page: A2:4
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2.3 MATERIAL

The are different cement types according to CEM (I-V) depending on amount of furnace ash. In this case cement type I ($\leq 5\%$ furnace ash) is used.

Isotropic thermal material below is applied to wet concrete to determines temperature in slab.

Isotropic

Thermal

	Value
Thermal conductivity	2.0
Specific heat capacity	1.0448E3
Density	2.4E3

Exothermic behaviour

None
 Concrete Heat of Hydration

Cement type

	Value
Mass of cement per unit volume	390.0
Water/Cementitious mass ratio	0.45
Mass of slag per unit volume	0.0
Mass of fly ash per unit volume	0.0
CaO content of fly ash (%)	0.0
Delay for heat of hydration	0.0

Advanced...

Name (2)

Remark

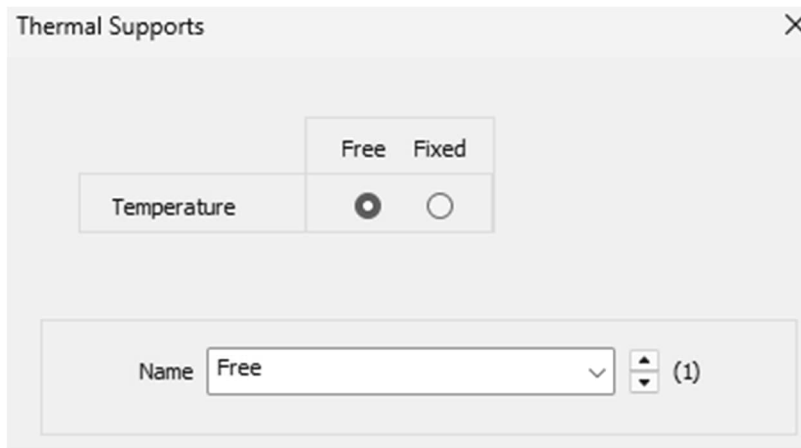
In this analysis no stress or crack width has been studied. This requires definition of structural nonlinear material properties.

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2.4 BOUNDARY CONDITIONS

2.4.1 Thermal boundary condition

To all surfaces *thermal boundary conditions* are set as free, thus always surface temperature follows environment.



2.4.2 Structural boundary condition

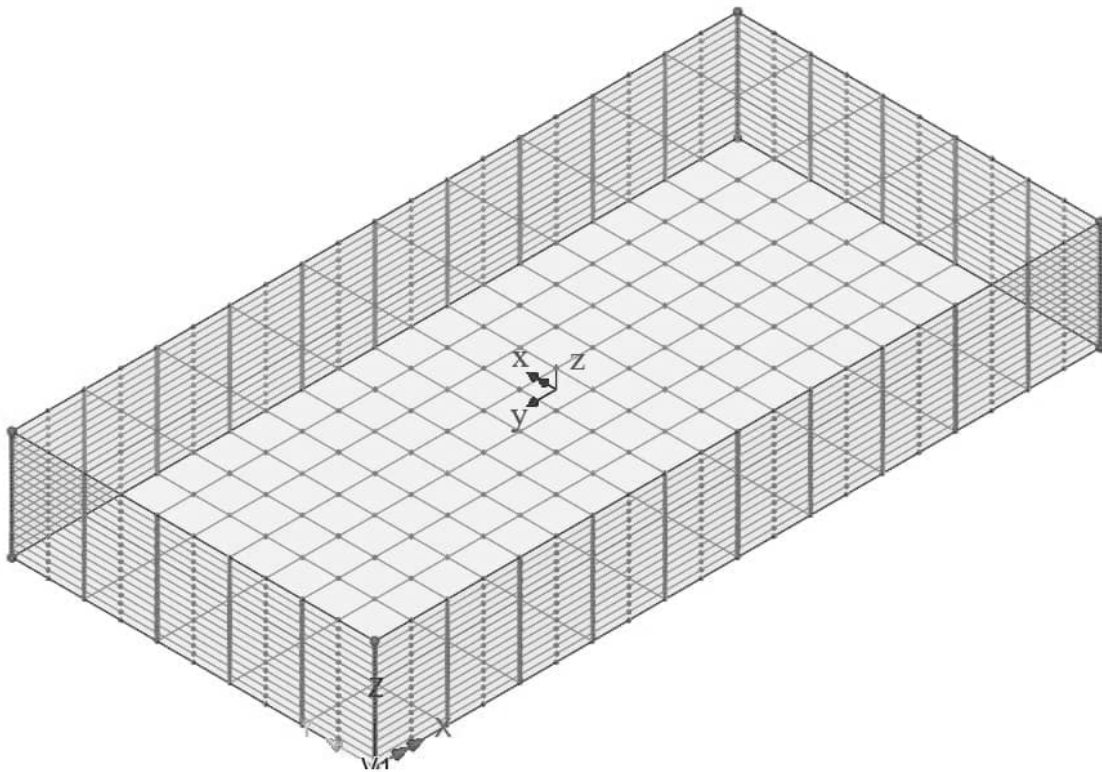
In this analysis no stress or crack width has been studied, thus no structural boundary conditions have been applied.

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2.5 MESH

Studied slab is modelled as a thermal volume field element ("Volume hexahedral"/ HF20).

Name	Division x-direction	Division y-direction	Division z-direction
Solide	5	10	15



3D overview

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3. THERMAL LOADING

- 3.1 CONSTANT AMBIENT TEMPERATURE
- 3.2 VARYING AMBIENT TEMPERATURE

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page 3:13-22

	Part A - CALCULATION ASSUMPTIONS	Status :	Page: A3:2
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3.1 CONSTANT AMBIENT TEMPERATURE: ANALYSIS 1

Loads are applied thermal loads with constant environmental conditions.

3.1.1 Load curves

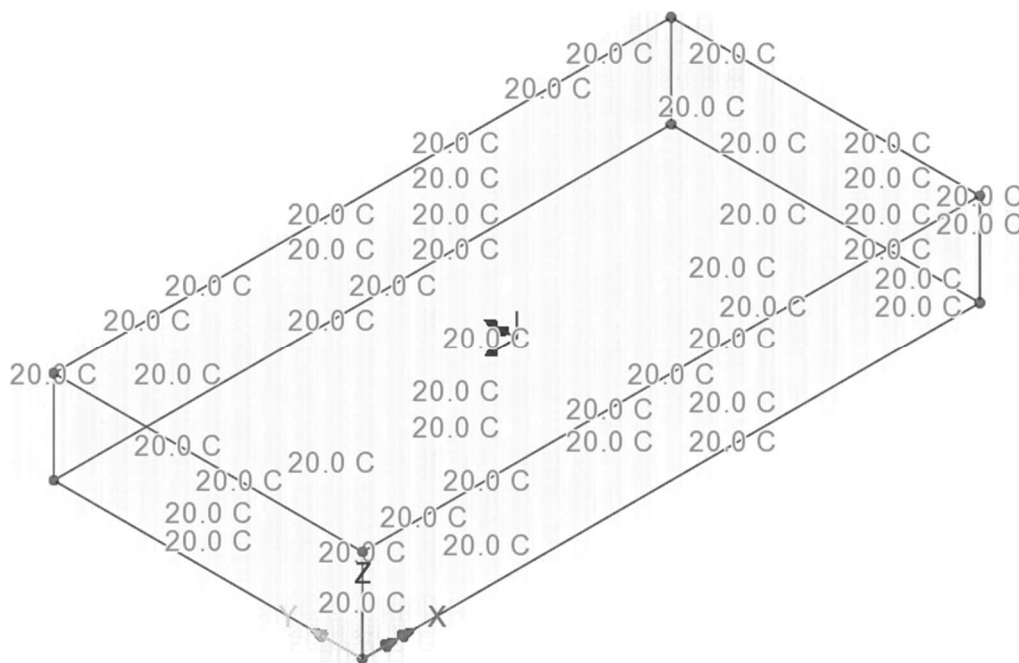
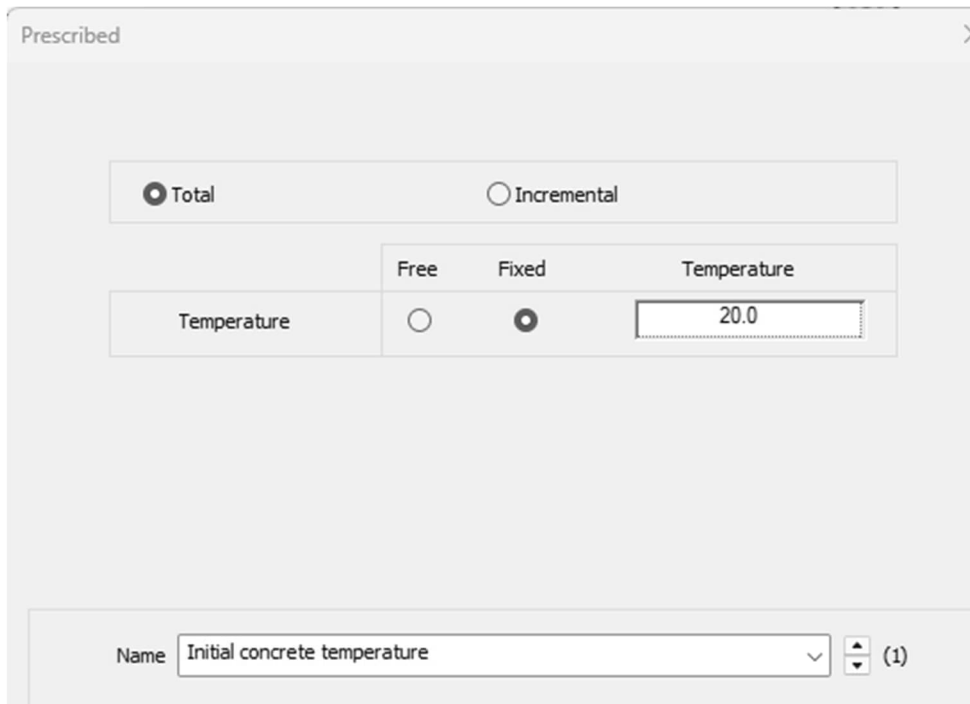
Since thermal loads are constant no load curves are used.

	Part A - CALCULATION ASSUMPTIONS	Status :	Page: A3:3
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3.1.2 Concrete temperature

Initial concrete temperature at casting (T_{cast}) is +20° C. This loadcase is applied to entire slab.

Load: Initial temperature



3D VIEW

	Part A - CALCULATION ASSUMPTIONS	Status :	Page: A3:4
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Loadcase : Casting stage – analysis 1

Analysis: Analysis 1

Load: Initial temperature

Load curve: None

	Part A - CALCULATION ASSUMPTIONS	Status :	Page: A3:5
	Transient hygro-thermal analysis during concrete hardening: concrete slab	Date :	Created :

3.1.3 Ground temperature

Ground temperature (T_{soil}) is considered to be constantly $+10^{\circ}\text{C}$. This loadcase is applied to bottom face of slab. This load is applied to loadcases before (“Formwork for formwork”) and after (“Exposed until 30 days”) removal of formwork.

Loads is applied thermal loads using constant environmental conditions.

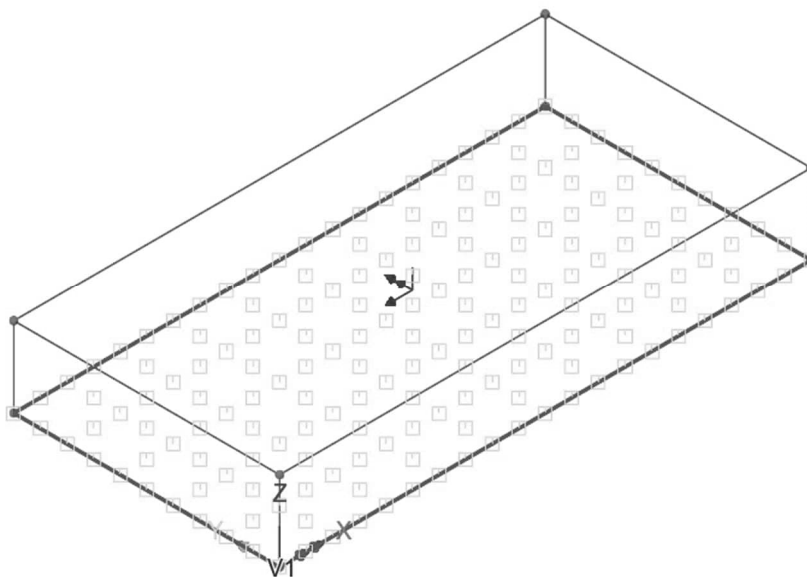
Load: Ground temperature

Environment Conditions ✕

Temperature dependent

	Environmental temperature	Convection heat transfer coefficient	Radiation heat transfer coefficient
1	10.0	2.8	0.0

Name (2)



3D VIEW

	Part A - CALCULATION ASSUMPTIONS	Status :	Page: A3:6
	Transient hygro-thermal analysis during concrete hardening: concrete slab	Date :	Created :

Loadcase : "Formwork for 3 days"

Analysis: Analysis 1
Thermal loading: " Ground temperature
Environmental temperature : +10° C.
Convection heat transfer coefficient: 2.8
Radiation heat transfer coefficient: 0
Load curve: None

Loadcase : "Exposed until 30 days"

Analysis: Analysis 1
Thermal loading: Ground temperature
Environmental temperature : +10° C.
Convection heat transfer coefficient: 2.8
Radiation heat transfer coefficient: 0
Load curve: None

	Part A - CALCULATION ASSUMPTIONS	Status :	Page: A3:7
	Transient hygro-thermal analysis during concrete hardening: concrete slab	Date :	Created :

3.1.4 Formwork temperature

Temperature (T_{aorm}) is considered to be constantly +20° C. This loadcase is applied to external side faces of slab. This load is applied to loadcases before (“Formwork for 3 days”).

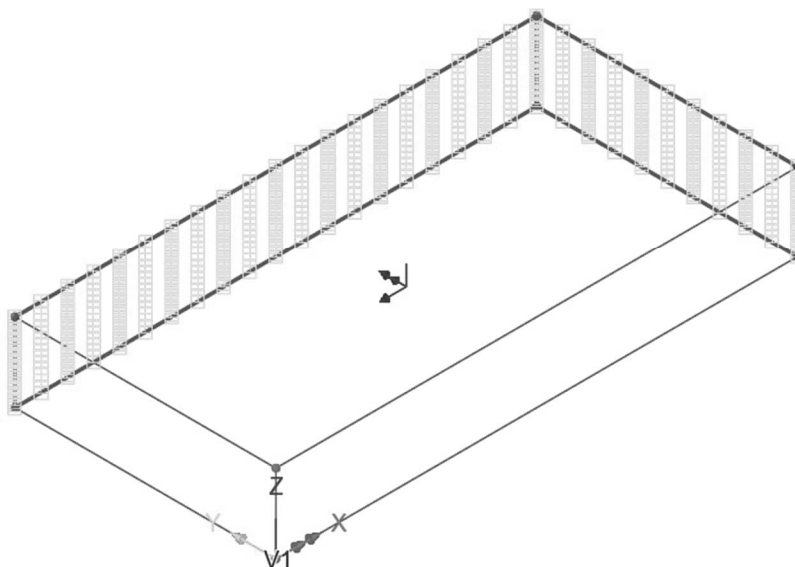
Load: Formwork temperature

Environment Conditions ✕

Temperature dependent

	Environmental temperature	Convection heat transfer coefficient	Radiation heat transfer coefficient
1	20.0	7.0	0.0

Name (3)



3D VIEW

	Part A - CALCULATION ASSUMPTIONS	Status :	Page: A3:8
	Transient hygro-thermal analysis during concrete hardening: concrete slab	Date :	Created :

Loadcase : "Formwork for 3 days"

Analysis:	Analysis 1
Thermal loading:	Formwork temperature
Environmental temperature :	+20° C.
Convection heat transfer coefficient:	7.0
Radiation heat transfer coefficient:	0
Load curve:	None

	Part A - CALCULATION ASSUMPTIONS	Status :	Page: A3:9
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3.1.5 Removed formwork temperature

Air temperature (T_{aorm}) is considered to be constantly $+20^{\circ}$ C. This loadcase is applied to external side faces of slab. This load is applied to loadcases after removal of formwork (“Exposed until 30 days”).

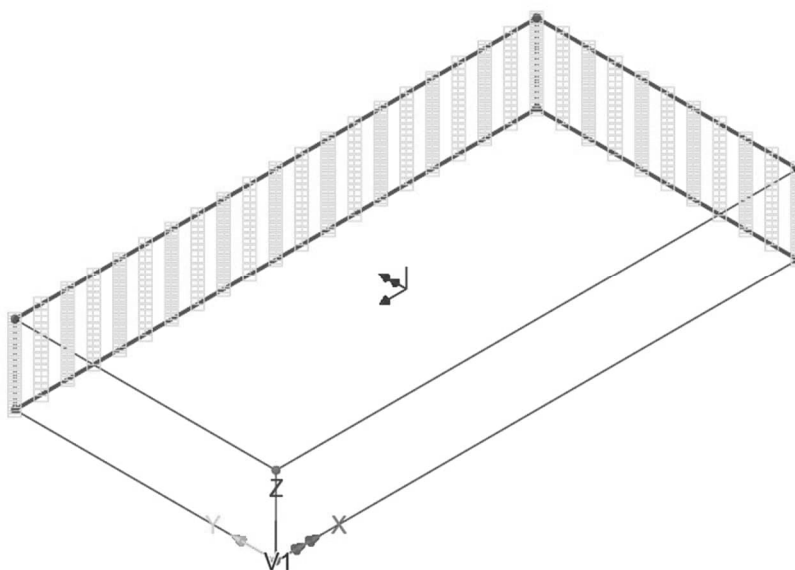
Load: Removed formwork temperature

Environment Conditions ✕

Temperature dependent

	Environmental temperature	Convection heat transfer coefficient	Radiation heat transfer coefficient
1	20.0	8.3	0.0

Name (5)



3D VIEW

	Part A - CALCULATION ASSUMPTIONS	Status :	Page: A3:10
	Transient hygro-thermal analysis during concrete hardening: concrete slab	Date :	Created :

Loadcase : "Exposed until 30 days"

Analysis:	Analysis 1
Thermal loading:	Removed formwork temperature
Environmental temperature :	+20° C
Convection heat transfer coefficient:	8.3
Radiation heat transfer coefficient:	0
Load curve:	None

	Part A - CALCULATION ASSUMPTIONS	Status :	Page: A3:11
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3.1.6 Air temperature

Air temperature (T_{air}) is considered to be constantly $+20^{\circ}$ C. This loadcase is applied top face of slab. This load is applied to loadcases before (“Formwork for formwork”) and after (“Exposed until 30 days”) removal of formwork.

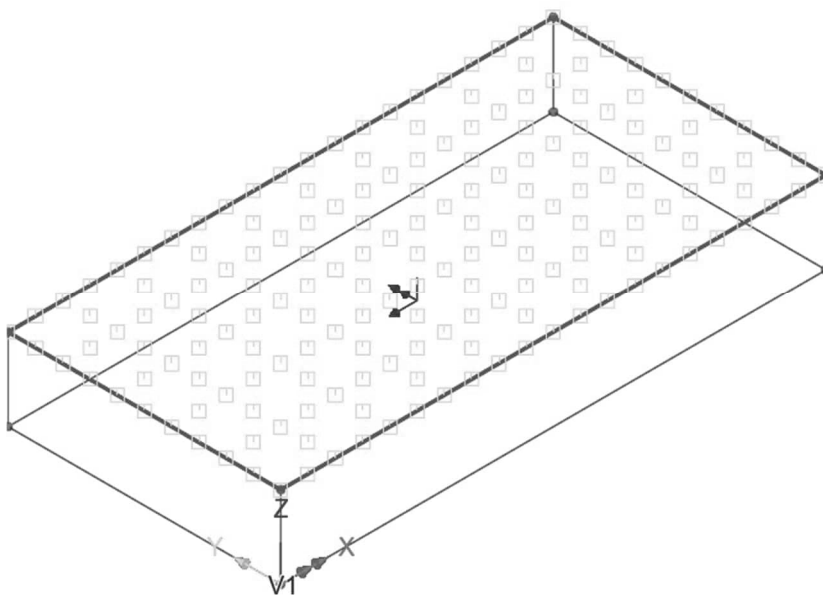
Load: Air temperature

Environment Conditions ✕

Temperature dependent

	Environmental temperature	Convection heat transfer coefficient	Radiation heat transfer coefficient
1	20.0	8.3	0.0

Name (3)



3D VIEW

	Part A - CALCULATION ASSUMPTIONS	Status :	Page: A3:12
	Transient hygro-thermal analysis during concrete hardening: concrete slab	Date :	Created :

Loadcase : "Formwork for 3 days"

Analysis: Analysis 1

Thermal loading: Air temperature

Environmental temperature : +20° C

Convection heat transfer coefficient: 8.3

Radiation heat transfer coefficient: 0

Load curve: None

Loadcase : "Exposed until 30 days"

Analysis: Analysis 1

Thermal loading: Air temperature

Environmental temperature : +20° C.

Convection heat transfer coefficient: 8.3

Radiation heat transfer coefficient: 0

Load curve: None

	Part A - CALCULATION ASSUMPTIONS	Status :	Page: A3:13
	Transient hygro-thermal analysis during concrete hardening: concrete slab	Date :	Created :

3.2 VARYING AMBIENT TEMPERATURE: ANALYSIS 2

The analysis is same as for constant ambient air temperature (ANALYSIS 1) cyclic varying air temperature.

This is achieved by applying varying load curves.

3.2.1 Load curves

Air temperature varies from day to night cyclic using load curves.

Load curve during casting of concrete

Name load curve: Casting stage curve

Type: User-defined (table)

Time	Factor
0	1
0.001	1
days	-

Activation time: 0 days

Load curve for ground temperature

Name load curve: Ground surface curve

Type: User-defined (table)

Time	Factor
0	1
30	1
days	-

Activation time: 0 days

..

	Part A - CALCULATION ASSUMPTIONS	Status :	Page: A3:14
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Load curve air temperature day 0 → 3 day

Name load curve: Day-night curve 3 days
Type: Cosine
Amplitude: 10
Mean value: 20
Frequency: 1 day
Activation time: 0 days

Load curve air temperature day 3 → 30 day

Name load curve: Day-night curve 3 to 30 days
Type: Cosine
Amplitude: 10
Mean value: 20
Frequency: 1 day
Activation time: 3 days

	Part A - CALCULATION ASSUMPTIONS	Status :	Page: A3:15
	Transient hygro-thermal analysis during concrete hardening: concrete slab	Date :	Created :

3.2.2 Concrete temperature

Initial concrete temperature at casting (T_{cast}) is +20° C. This loadcase is applied to entire slab.

Loadcase : Casting stage – analysis 2

Load: Initial concrete temperature

Load curve: Casting stage curve

	Part A - CALCULATION ASSUMPTIONS	Status :	Page: A3:16
	Transient hygro-thermal analysis during concrete hardening: concrete slab	Date :	Created :

3.2.3 Ground temperature

Ground temperature (T_{soil}) is considered to be constantly $+10^{\circ}$ C. This loadcase is applied to bottom face of slab. This load is constant.

Loadcase : Ground surface curve

Load: Ground temperature

Load curve: Ground surface curve

	Part A - CALCULATION ASSUMPTIONS	Status :	Page: A3:17
	Transient hygro-thermal analysis during concrete hardening: concrete slab	Date :	Created :

3.2.4 Formwork temperature

Temperature (T_{aorm}) is considered to be constantly +20° C. This loadcase is applied to external side faces of slab. This load is applied to loadcases before (“Formwork for 3 days”).

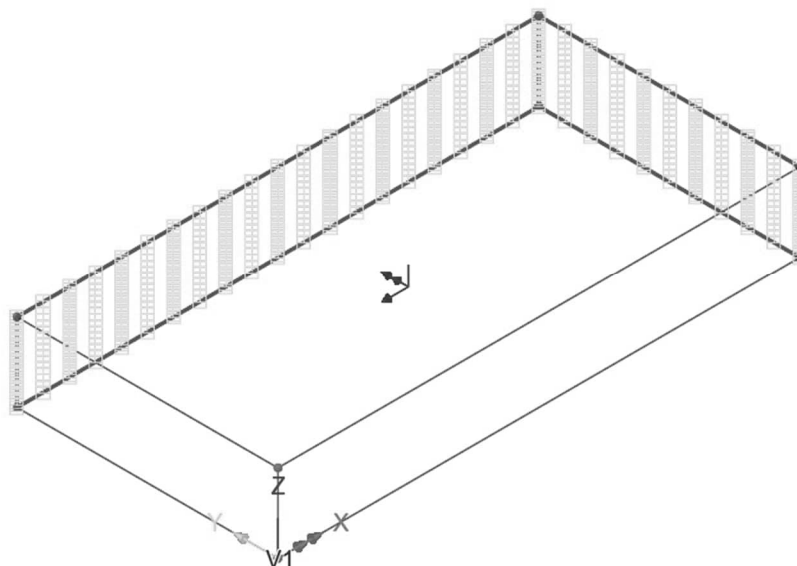
Load: Unit - Formwork temperature

Environment Conditions ✕

Temperature dependent

	Environmental temperature	Convection heat transfer coefficient	Radiation heat transfer coefficient
1	1.0	8.3	0.0

Name (7)



3D VIEW

	Part A - CALCULATION ASSUMPTIONS	Status :	Page: A3:18
	Transient hygro-thermal analysis during concrete hardening: concrete slab	Date :	Created :

Loadcase : "Formwork for 3 days"

Analysis: Analysis 2

Thermal loading: Unit - Formwork temperature

Environmental temperature : +1° C (unit load)

Convection heat transfer coefficient: 7.0

Radiation heat transfer coefficient: 0

Load curve: Day-night curve 3 days

Remark

Unit load is amplified using load-curve so varies cyclic +10° C → +30° C.

	Part A - CALCULATION ASSUMPTIONS	Status :	Page: A3:19
	Transient hygro-thermal analysis during concrete hardening: concrete slab	Date :	Created :

3.2.5 Removed formwork temperature

Air temperature (T_{aorm}) is considered to be constantly $+20^{\circ}$ C. This loadcase is applied to external side faces of slab. This load is applied to loadcases after removal of formwork (“Exposed until 30 days”).

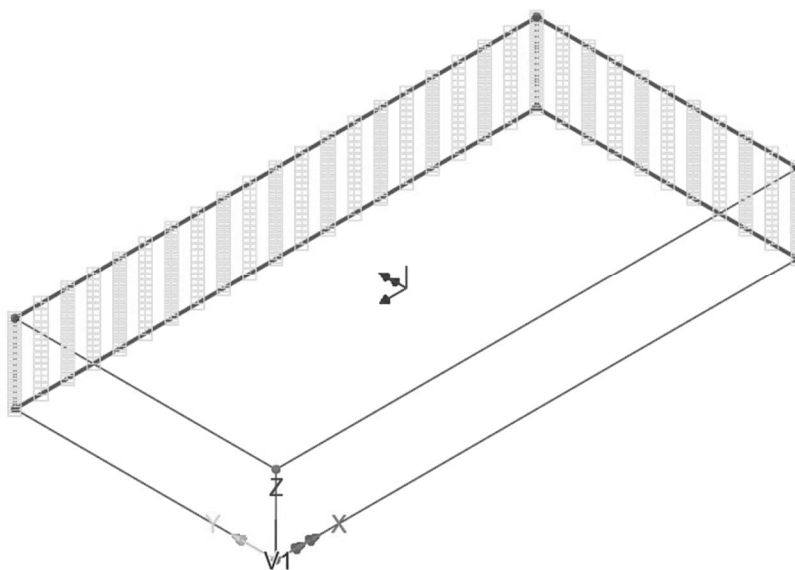
Load: Unit - Removed formwork temperature

Environment Conditions ✕

Temperature dependent

	Environmental temperature	Convection heat transfer coefficient	Radiation heat transfer coefficient
1	1.0	8.3	0.0

Name (7)



3D VIEW

	Part A - CALCULATION ASSUMPTIONS	Status :	Page: A3:20
	Transient hygro-thermal analysis during concrete hardening: concrete slab	Date :	Created :

Loadcase : "Exposed until 30 days"

Analysis: Analysis 1

Thermal loading: Removed formwork temperature

Environmental temperature : +1° C (unit load)

Convection heat transfer coefficient: 8.3

Radiation heat transfer coefficient: 0

Load curve: Day-night curve 3 to 30 days

Remark

Unit load is amplified using load-curve so varies cyclic +10° C → +30° C.

	Part A - CALCULATION ASSUMPTIONS	Status :	Page: A3:21
	Transient hygro-thermal analysis during concrete hardening: concrete slab	Date :	Created :

3.2.6 Air temperature

Air temperature (T_{air}) is considered to be constantly $+20^{\circ}\text{C}$. This loadcase is applied top face of slab. This load is applied to loadcases before (“Formwork for formwork”) and after (“Exposed until 30 days”) removal of formwork.

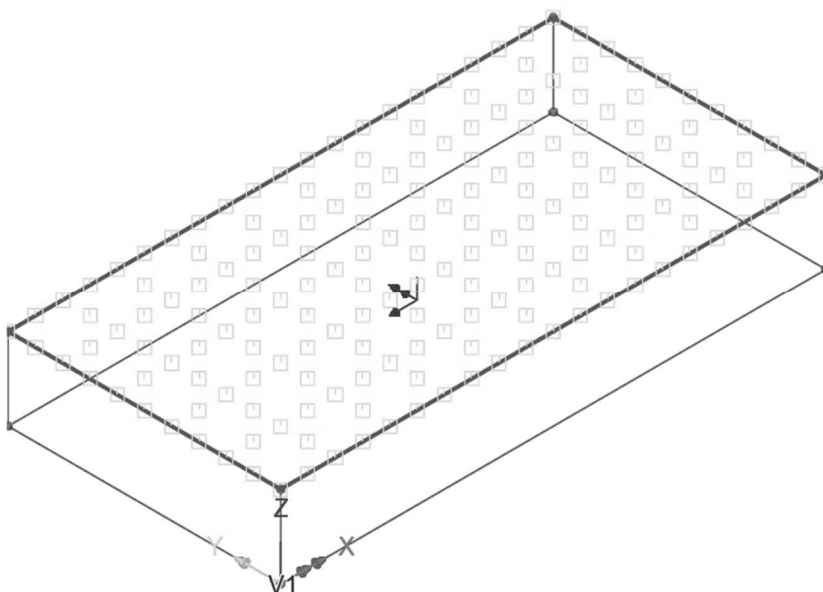
Load: Unit- Air temperature

Environment Conditions ✕

Temperature dependent

	Environmental temperature	Convection heat transfer coefficient	Radiation heat transfer coefficient
1	1.0	8.3	0.0

Name (8)



3D VIEW

	Part A - CALCULATION ASSUMPTIONS	Status :	Page: A3:22
	Transient hygro-thermal analysis during concrete hardening: concrete slab	Date :	Created :

Loadcase : "Formwork for 3 days"

Analysis: Analysis 1

Thermal loading: Unit - Air temperature

Environmental temperature : +1° C (unit load)

Convection heat transfer coefficient: 8.3

Radiation heat transfer coefficient: 0

Load curve: Day-night curve 3 days

Loadcase : "Exposed until 30 days"

Analysis: Analysis 1

Thermal loading: Air temperature

Environmental temperature : +1° C (unit load)

Convection heat transfer coefficient: 8.3

Radiation heat transfer coefficient: 0

Load curve: Day-night curve 3 to 30 days

Remark

Unit load is amplified using load-curve so varies cyclic +10° C → +30° C.

	Part A - CALCULATION ASSUMPTIONS Transient hygro-thermal analysis during concrete hardening: concrete slab	Status :	Page: A4:1
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4. RESULTS

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4.2	TEMPERATURE ANALYSIS	page 4:2
4.3	STRUCTURAL ANALYSIS	page 4:2

	Part A - CALCULATION ASSUMPTIONS	Status :	Page: A4:2
	Transient hygro-thermal analysis during concrete hardening: concrete slab	Date :	Created :

4.1 WORKFLOW

Principal workflow for transient hygro-thermal analysis:

1. Generate static 3D model using volume elements.
2. Define thermal nonlinear transient material properties of concrete.
3. Define structural material properties of concrete (not performed in example).
4. Define thermal transient boundary conditions.
5. Define structural boundary conditions (not performed in example).
6. Define thermal transient loads.
7. Perform transient thermal analysis to determine temperature.
8. Perform transient structural analysis to determine stress, crack risk and crack width (not performed in example).

4.2 TEMPERATURE ANALYSIS

See appendix 2.

4.3 STRUCTURAL ANALYSIS

Not performed in example.

	Appendix 1: Input receipt SYSTEM 001 Transient hygro-thermal analysis during concrete hardening: concrete slab	Status :	Page: 1
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Title: Input receipt

Model Units: kN,m,t,s,C
Report Units: kN,m,t,s,C

Model Title: System 001
Model File: System 001

Clarification of definitions.

In the report, the letter “T” is used to describe a range. The letter is an abbreviation of “to”.

See example of assignment below.

Assignment to Lines:
105T110;114T119

This expression means that the assignment occurs to the lines L105 → L110 and L114 → L119.

Assignment to Surfaces:
3T17;19T24

This expression means that the assignment occurs to the surfaces S3 → S17 and S19 → S24.

	Appendix 1: Input receipt SYSTEM 001 Transient hygro-thermal analysis during concrete hardening: concrete slab	Status :	Page: 2
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	Appendix 1: Input receipt SYSTEM 001 Transient hygro-thermal analysis during concrete hardening: concrete slab	Status :	Page: 3
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1. Points

Point	X coordinate	Y coordinate	Z coordinate
1	0.0	0.0	3.0
2	0.0	0.0	0.0
3	0.0	10.0	3.0
4	0.0	10.0	0.0
5	20.0	0.0	3.0
6	20.0	0.0	0.0
7	20.0	10.0	3.0
8	20.0	10.0	0.0

2. Lines

Line	Points	Line	Points
1	2,1	2	1,3
3	3,4	4	4,2
5	5,6	6	7,5
7	8,7	8	6,8
9	2,6	10	5,1
11	8,4	12	3,7

3. Surfaces

Surface	Lines	Surface	Lines
1	1,2,3,4	2	5,8,7,6
3	9,5,10,1	4	11,3,12,7
5	4,11,8,9	6	2,10,6,12

4. Volumes

Volume	Surfaces
1	5,6,1,2,3,4

5. MESH: Volume

Attribute: 2
Sub Type = Volume Mesh

Title: Solide
Element Type = HF20

Property	Symbol	Value
Element size	size	-1.0
Number of divisions in x	xDivisions	5
Number of divisions in y	yDivisions	10
Number of divisions in z direction	zDivisions	15
Transition mesh	transition	false
Allow irregular mesh	allowIrregular	false
Element defined by name	DefinedByName	false
Single feature joint	isSingleFtrJnt	false

Assignment to Volumes: 1

	Appendix 1: Input receipt SYSTEM 001 Transient hygro-thermal analysis during concrete hardening: concrete slab	Status :	Page: 4
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6. Material

Attribute: 2 Title: C35/45

Sub Type = Isotropic Material

Assigned in: Analysis 1

Property	Symbol	Value
Mass of cement per unit volume	wcem	0.4
Mass of slag per unit volume	wslg	0.0
Mass of fly ash per unit volume	wpfa	0.0
Delay for heat of hydration	admix 1	0.0
Water/Cementitious mass ratio	wcra	0.5
CaO content of fly ash (%)	pfacao	0.0
C3S content (%)	C3S	0.0
C2S content (%)	C2S	0.0
C3A content (%)	C3A	0.0
C4AF content (%)	C4AF	0.0
Free CaO content (%)	FCaO	0.0
SO3 content (%)	SO3	0.0
MgO content (%)	MgO	0.0
Blaine value	Blaine	0.0
Cement type	icem	"Type I"
Ultimate degree of hydration	rdh	1.0
Heat of hydration	rhH	1.0
Hydration time	rht	1.0
Activation energy	rae	1.0
Hydration slope	rhs	1.0

Assignment to Volumes: 1

7. Boundary condition: thermal

Attribute: 1 Title: Free

Sub Type = Thermal Support

Assigned in: Analysis 1

Property	Symbol	Value
Reference temperature	T	"F"
Stiffness distribution type	springType	"Total"
Conductance	Tstiff	0.0
Capillary pressure stiffness	CPStiff	0.0

Assignment to Surfaces: 5,6,1,2,3,4

	Appendix 1: Input receipt SYSTEM 001 Transient hygro-thermal analysis during concrete hardening: concrete slab	Status :	Page: 5
		Date :	Created:

8. Load curves

Attribute: 6

Title: Casting stage curve

Type: Uses-defined table

Time	Factor
0	1
0.001	1

Activation time: 0 days

Attribute: 7

Title: Ground surface curve

Type: Uses-defined table

Time	Factor
0	1
30	1

Activation time: 0 days

Attribute: 8

Title: Day-night curve 3 days

Type: Cosine

Amplitude: 10

Mean value: 20

Frequency: 1

Activation time: 0

Attribute: 9

Title: Day-night curve 3 to 30 days

Type: Cosine

Amplitude: 10

Mean value: 20

Frequency: 1

Activation time: 3

	Appendix 1: Input receipt SYSTEM 001 Transient hygro-thermal analysis during concrete hardening: concrete slab	Status :	Page: 6
		Date :	Created:

9. Loads: thermal

Attribute: 1

Title: Initial concrete temperature

Sub Type = Prescribed Temperature

Property	Symbol	Value
Attribute type	type	"Total"
Prescribed temperature	T	20.0
Fixed temperature	havePhi	true
Humidity	humidity	0.0
Fixed humidity	haveHumidity	false
Saturation	saturation	0.0
Fixed Saturation	haveSaturation	false
using humidity	isDlghumidity	false

Loadcase ID: 1

Title: Casting stage - analysis 1

Factor = 1.0

Assigned in: Analysis 1

Assignment to Volumes: 1

Loadcase ID: 6

Title: Casting stage - analysis 2

Assigned in: Analysis 2

Factor = "Casting stage curve"

Assignment to Volumes: 1

Attribute: 2

Title: Ground temperature

Sub Type = Environmental

Property	Symbol	Value
Environmental temperature	envT	10.0
Convection heat transfer coefficient	hc	0.0
Radiation heat transfer coefficient	hr	0.0
Relative humidity	humidity	0.0
Vapour mass transfer coefficient	vapourMass	0.0
Reference temperature	T	0.0

Loadcase ID: 2

Title: Formwork for 3 days

Factor = 1.0

Assigned in: Analysis 1

Assignment to Surfaces: 5

Loadcase ID: 3

Title: Exposed until 30 days

Factor = 1.0

Assigned in: Analysis 1

Assignment to Surfaces: 5

Loadcase ID: 7

Title: Ground surface curve

Factor = "Constant ground surface curve"

Assigned in: Analysis 2

Assignment to Surfaces: 5

	Appendix 1: Input receipt SYSTEM 001	Status :	Page: 7
	Transient hygro-thermal analysis during concrete hardening: concrete slab	Date :	Created:

Attribute: 3

Title: Formwork temperature

Sub Type = Environmental

Property	Symbol	Value
Environmental temperature	envT	20.0
Convection heat transfer coefficient	hc	0.0
Radiation heat transfer coefficient	hr	0.0
Relative humidity	humidity	0.0
Vapour mass transfer coefficient	vapourMass	0.0
Reference temperature	T	0.0

Loadcase ID: 2

Title: Formwork for 3 days

Factor = 1.0

Assigned in: Analysis 1

Assignment to Surfaces: 2;4

Attribute: 4

Title: Removed formwork temperature

Sub Type = Environmental

Property	Symbol	Value
Environmental temperature	envT	20.0
Convection heat transfer coefficient	hc	0.0
Radiation heat transfer coefficient	hr	0.0
Relative humidity	humidity	0.0
Vapour mass transfer coefficient	vapourMass	0.0
Reference temperature	T	0.0

Loadcase ID: 3

Title: Exposed until 30 days

Factor = 1.0

Assigned in: Analysis 1

Assignment to Surfaces: 2;4

Attribute: 5

Title: Air Temperature

Sub Type = Environmental

Property	Symbol	Value
Environmental temperature	envT	20.0
Convection heat transfer coefficient	hc	0.0
Radiation heat transfer coefficient	hr	0.0
Relative humidity	humidity	0.0
Vapour mass transfer coefficient	vapourMass	0.0
Reference temperature	T	0.0

Loadcase ID: 2

Title: Formwork for 3 days

Factor = 1.0

Assigned in: Analysis 1

Assignment to Surfaces: 6

Loadcase ID: 3

Title: Exposed until 30 days

Factor = 1.0

Assigned in: Analysis 1

Assignment to Surfaces: 6

Attribute: 6

	Appendix 1: Input receipt SYSTEM 001	Status :	Page: 8
	Transient hygro-thermal analysis during concrete hardening: concrete slab	Date :	Created:

Title: Unit - Formwork Temperature

Sub Type = Environmental

Property	Symbol	Value
Environmental temperature	envT	1.0
Convection heat transfer coefficient	hc	0.0
Radiation heat transfer coefficient	hr	0.0
Relative humidity	humidity	0.0
Vapour mass transfer coefficient	vapourMass	0.0
Reference temperature	T	0.0

Loadcase ID: 8

Title: Day-night curve 3 days

Factor = " Day-night curve 3 days"

Assigned in: Analysis 2

Assignment to Surfaces: 2;4

Attribute: 7

Title: Unit - Removed formwork temperature

Sub Type = Environmental

Property	Symbol	Value
Environmental temperature	envT	1.0
Convection heat transfer coefficient	hc	0.0
Radiation heat transfer coefficient	hr	0.0
Relative humidity	humidity	0.0
Vapour mass transfer coefficient	vapourMass	0.0
Reference temperature	T	0.0

Loadcase ID: 9

Title: Day-night curve 3 days

Factor = " Day-night curve 3 to 30 days"

Assigned in: Analysis 2

Assignment to Surfaces: 2;4

Attribute: 8

Title: Unit - Air temperature

Sub Type = Environmental

Property	Symbol	Value
Environmental temperature	envT	1.0
Convection heat transfer coefficient	hc	0.0
Radiation heat transfer coefficient	hr	0.0
Relative humidity	humidity	0.0
Vapour mass transfer coefficient	vapourMass	0.0
Reference temperature	T	0.0

Loadcase ID: 10

Title: Day-night curve 3 days

Factor = " Day-night curve 3 days"

Assigned in: Analysis 2

Assignment to Surfaces: 6

Loadcase ID: 11

Title: Day-night curve 3 to 30 days

Factor = " Day-night curve 3 to days"

Assigned in: Analysis 2

Assignment to Surfaces: 6

	Appendix 2: Results SYSTEM 001	Status :	Page: 1
	Transient hygro-thermal analysis during concrete hardening: concrete slab	Date :	Created:

Title: Results

Model Units: kN,m,t,s,C
Report Units: kN,m,t,s,C

Model Title: System 001
Model File: System 001

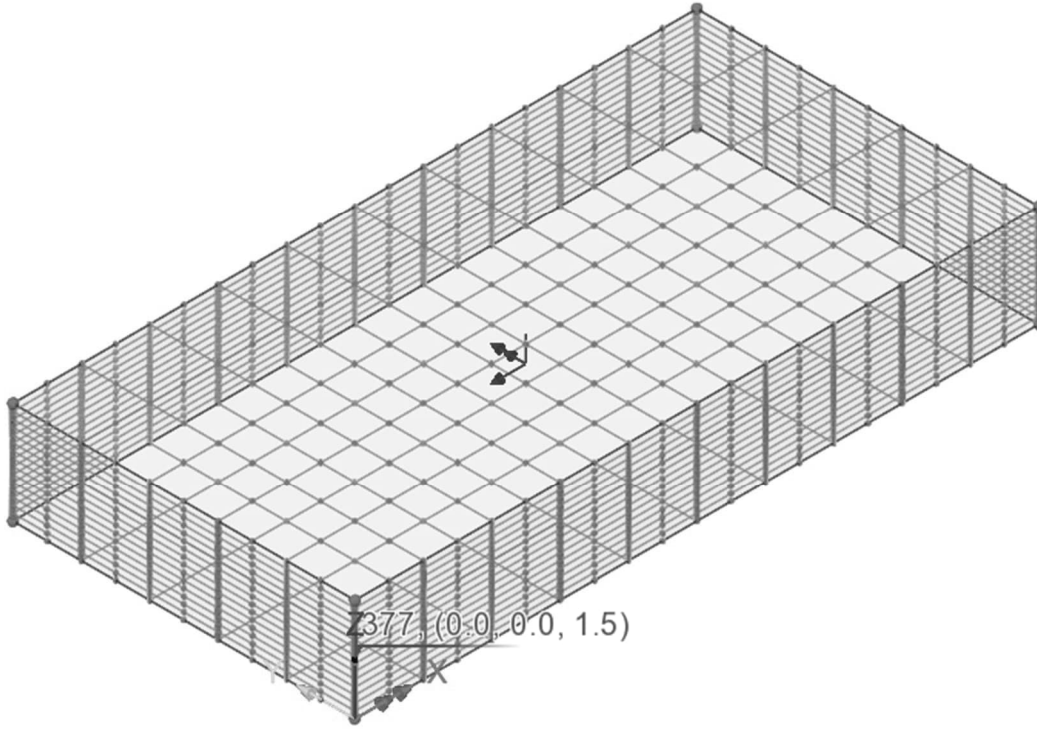
	Appendix 2: Results SYSTEM 001 Transient hygro-thermal analysis during concrete hardening: concrete slab	Status :	Page: 2
		Date :	Created:

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2.	Analysis 1: constant air temperature	4-5
3.	Analysis 2: cyclic air temperature	6-7
4.	Combined table analysis 1-2	8

	Appendix 2: Results SYSTEM 001 Transient hygro-thermal analysis during concrete hardening: concrete slab	Status :	Page: 3
		Date :	Created:

1. Result nodes



3D Overview
Location N377

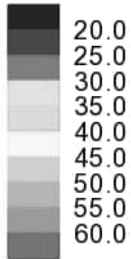
	Appendix 2: Results SYSTEM 001	Status :	Page: 4
	Transient hygro-thermal analysis during concrete hardening: concrete slab	Date :	Created:

2. Analysis 1: constant air temperature

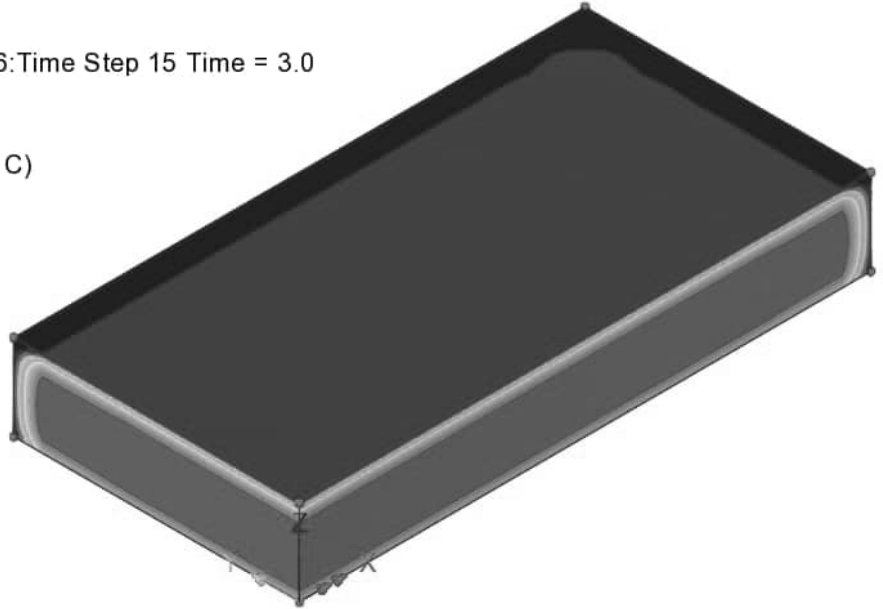
2.1 Contour temperature t = 3 days

Analysis: Analysis 2
Loadcase: 5:30 days Day-night, 16:Time Step 15 Time = 3.0

Entity: Temperature
Component (Nodal): Temp (Units: C)



Maximum 74.5758 at node 3035
Minimum 4.02491 at node 663

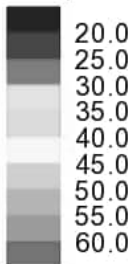


3D Overview

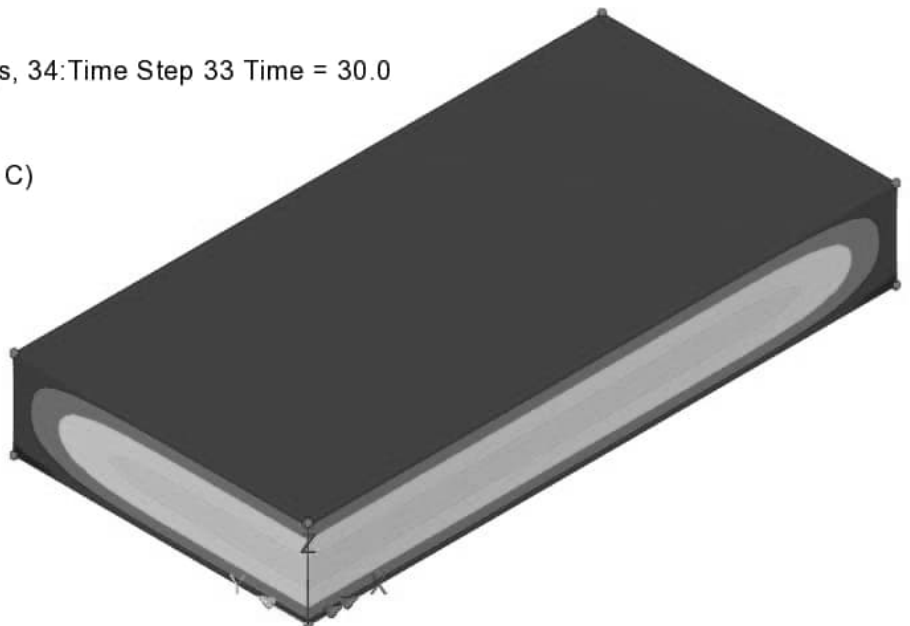
2.2 Contour temperature t = 30 days

Analysis: Analysis 1
Loadcase: 3:Exposed until 30 days, 34:Time Step 33 Time = 30.0

Entity: Temperature
Component (Nodal): Temp (Units: C)

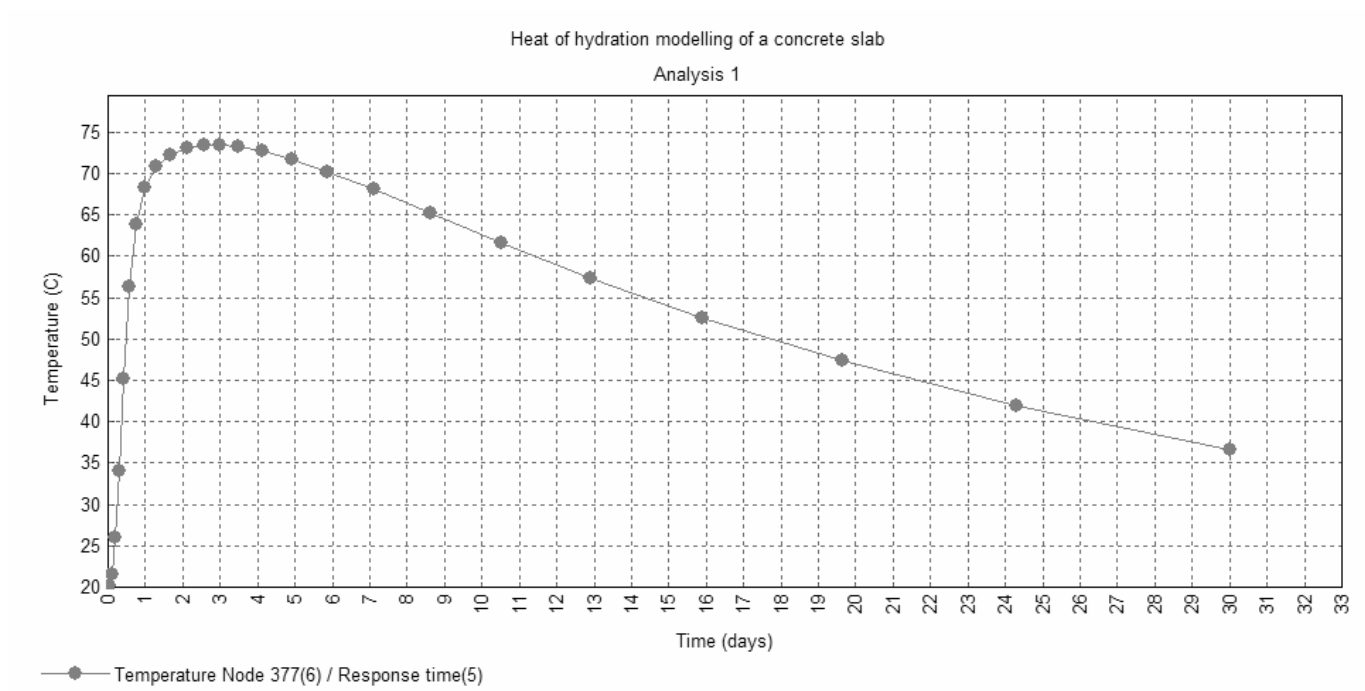


Maximum 36.3956 at node 377
Minimum 17.2038 at node 13



3D Overview

2.3 Table temperature at N377: t = 0 to 30 days



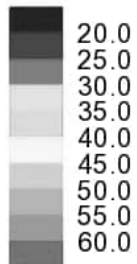
	Appendix 2: Results SYSTEM 001 Transient hygro-thermal analysis during concrete hardening: concrete slab	Status :	Page: 6
		Date :	Created:

3. Analysis 2: cyclic air temperature

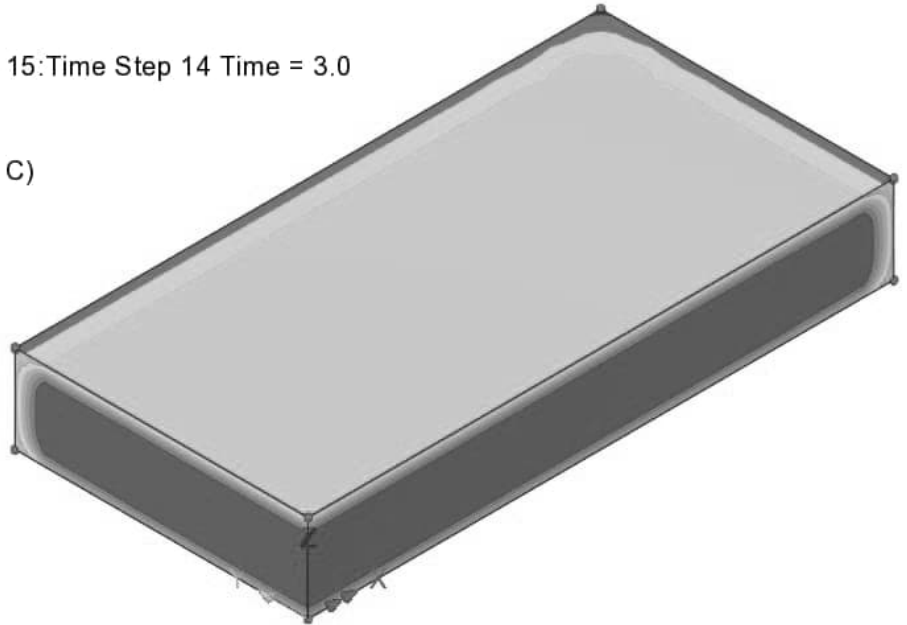
3.1 Contour temperature t = 3 days

Analysis: Analysis 1
Loadcase: 2:Formwork for 3 days, 15:Time Step 14 Time = 3.0

Entity: Temperature
Component (Nodal): Temp (Units: C)



Maximum 74.5136 at node 3035
Minimum 23.0036 at node 12

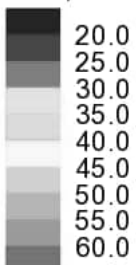


3D Overview

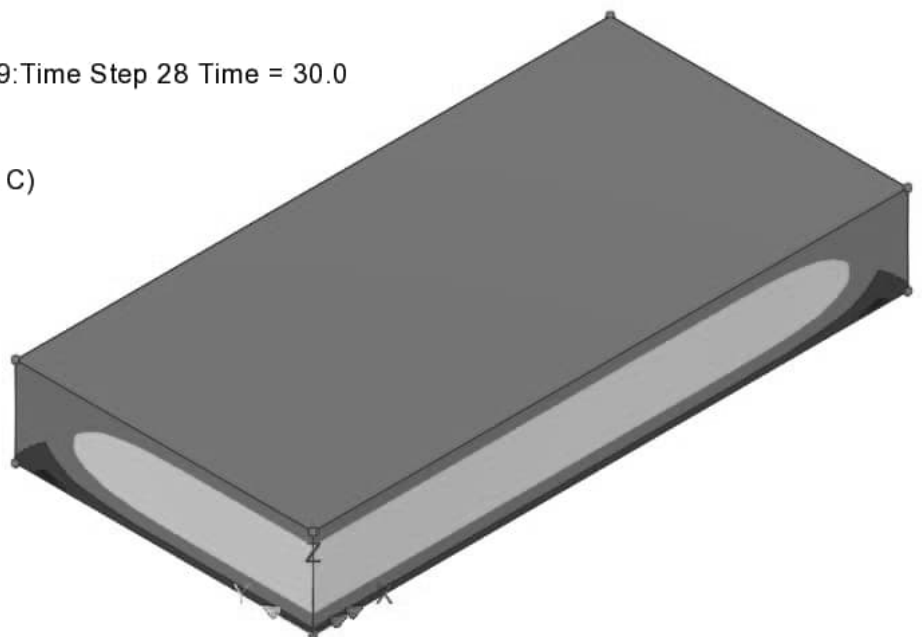
3.2 Contour temperature t = 30 days

Analysis: Analysis 2
Loadcase: 5:30 days Day-night, 29:Time Step 28 Time = 30.0

Response time: 30.0
Entity: Temperature
Component (Nodal): Temp (Units: C)



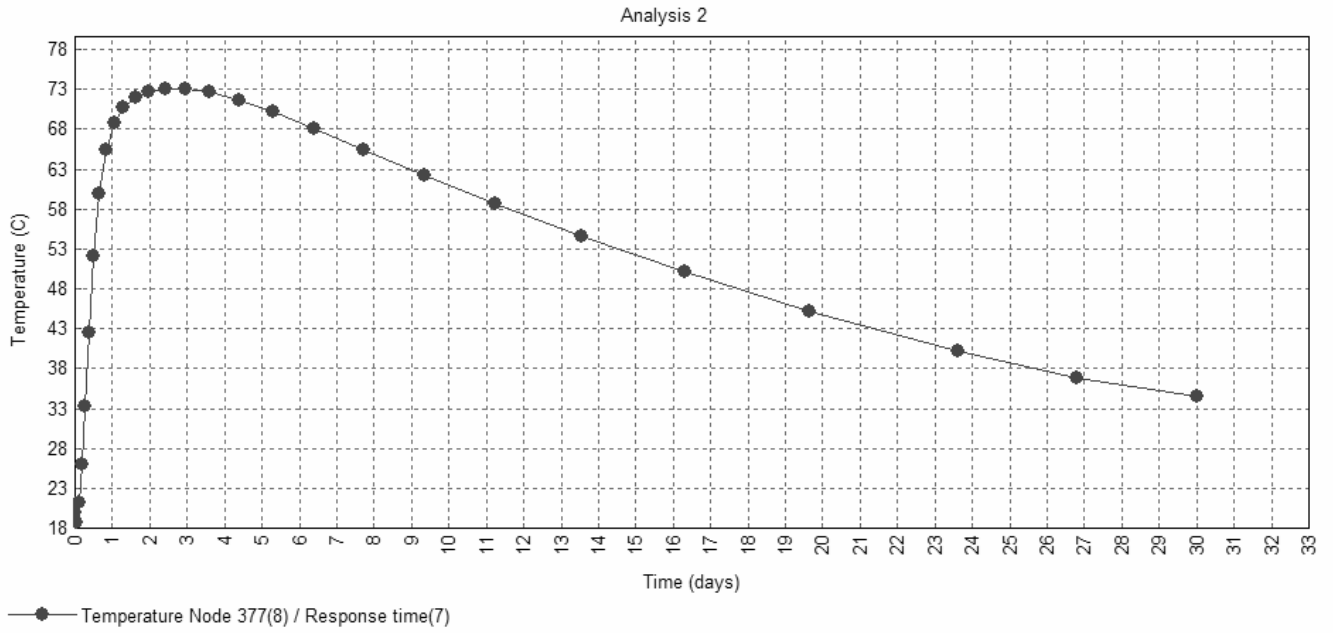
Maximum 34.4428 at node 377
Minimum 16.3649 at node 181



3D Overview

	Appendix 2: Results SYSTEM 001 Transient hygro-thermal analysis during concrete hardening: concrete slab	Status :	Page: 7
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3.3 Table temperature at N377: t = 0 to 30 days



4. Combined table of analysis 1-2

Table temperature at N377 (t = 0 to 30 days).

