TTNL03 - Thermohydration. Simulation of an adiabatic test

Summary:

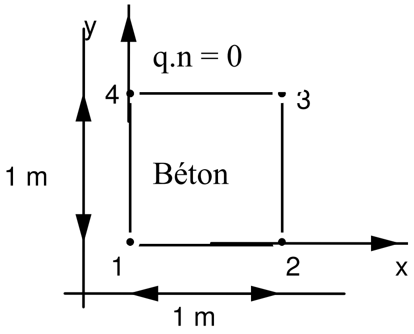
The purpose of this test is to validate the thermo-hydrating behavior `THER_HYDR`, by simulating an adiabatic test:
a freshly-mixed concrete sample is plunged in a calorimeter, the catch being carried out with heat emission, it is a question of finding the field of temperature and hydration in the course of time.

The temperature and the degree of hydration are uniform in the sample. The temperature measured in the calorimeter will be thus the reference solution, the hydration being determined by analytical integration of the law of evolution.

2 modelings are proposed: three-dimensional and axisymmetric.

1 Problem of reference

1.1 Geometry



1.2 Material properties

The material has the following thermal characteristics:

Thermal conductivity: $k_s = 6\,kJ/h/m/°K$

voluminal variation of enthalpy: $\Delta H = 2.4\,105\,kJ/m^3$,

and characteristics relating to the behavior hydrating following:

Heat per degree of hydration: $Q_0 = 1.4904105\,kJ/m^3$

Constant of Arrhenius: $Ar = 4000/°K$.

Note:

The constant of Arrhenius is always expressed in Kelvin degree. The temperatures are expressed in $°C$.

Affinity function of the hydration:

Degree of hydration h	**Affinity** $A(h)(1/h)$
0	6510
0,008	6360
0,016	2485
0,019	2460
0,038	9520
0,047	21800
0.08	37600
0,138	51600
0,232	51400
0,351	28200
0.44	16100
0.5	11700
0.63	5570
0.73	4240
0.81	1780
0.88	302
0.97	50
1.00	0

1.3 Boundary conditions and loadings

One imposes a heat flux no one on all the faces of the solid. The loading is only initiated by a source of heat depending on the hydration $\Delta Q=Q_0\Delta h$.

1.4 Initial conditions

The initial temperature is of $20.9°C$

1.5 Discretization in time

The explicit integration of the hydration requires a fine temporal discretization until the end of the phenomenon of hydration:

Of $t=0$ with $t=20\mathrm{h}$, $\Delta t=7{,}5\,min$ that is to say 160 pas.
Of $t=20\mathrm{h}$ with $t=60\mathrm{h}$, $\Delta t=1\,h$ that is to say 40 pas.

2 Reference solution

2.1 Method of calculating used for the reference solution

The reference solution in temperature is given by the temperatures measured at every moment during the adiabatic test.

The reference solution for the degree of hydration is calculated analytically according to the temperatures measured by integrating the law of evolution of the degree of hydration hy :

$$\Delta hy=A(h)e^{\frac{-Ar}{(T+273.15)}}\Delta t$$, T being expressed in $°C$

2.2 Results of Reference

The results relate to the first 60 hours of the test.

t (in h)	T (in $°C$)	hy (en%)
0	20.9	0
1	21.4	0.8
2	21.9	1.6
3	22.1	1.9
4	22.3	2.2
5	22.5	2.58
10	35.3	23.2
15	57.8	59.4
20	68.3	76
30	75.8	88
45	77.9	92
60	79.1	94

2.3 Uncertainty on the solution

Measurement of the temperatures during the test. Integration of the law of evolution of hy on steps of variable time between 1:00 and 5:00.

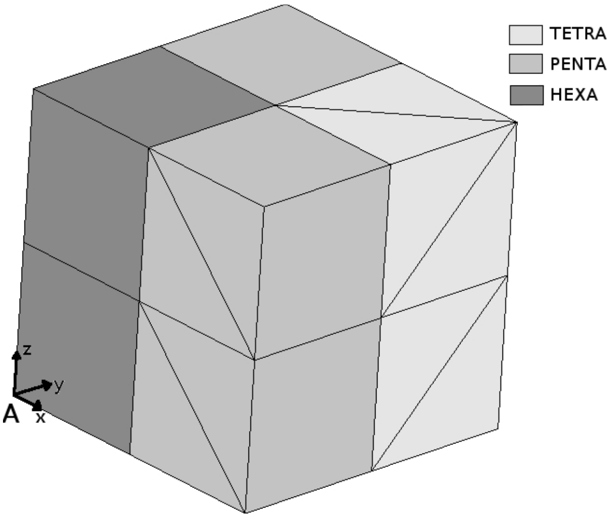
2.4 Bibliographical references

- CESAR-LCPC 3.2. Handbook of examples. Modeling of the concrete to the young age. January 1996
- Gilles DEBRUYNE: Analysis of models of behavior of the concrete in CESAR: transferability of model TEXO-MEXO in *Code_Aster*. CR MN 97-193. 12/24/97

3 Modeling A

3.1 Characteristics of modeling

Two calculations are carried out, one in modeling `3D` and the other `3D_DIAG`.



3.2 Characteristics of the grid

Many nodes: 29
Many meshs and types: 2 `HEXA8`, 8 `PENTA6`, 24 `TETRA4`

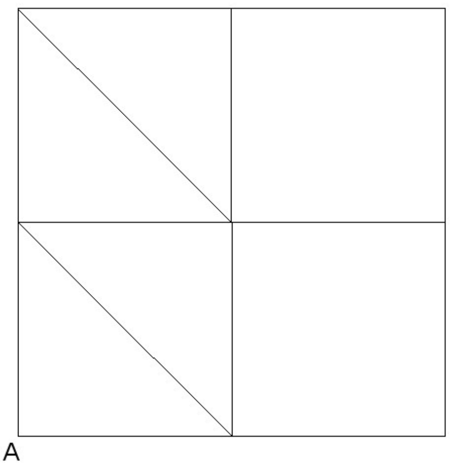
3.3 Sizes tested and results

Identification	**Moments**	**Reference**	***Aster 3D***	***Aster 3D_DIAG***	**% difference**
T node A	5	22.5	22.46	22.46	-0.19
T node A	15	57.8	58.35	58.35	0.95
T node A	60	79.1	78.84	78.84	-0.33
hy node A	15	0,594	0,603	0,603	1.5

4 Modeling B

4.1 Characteristics of modeling

Two calculations are carried out, one in modeling `AXIS` and the other `AXIS_DIAG`.



4.2 Characteristics of the grid

Many nodes: 9
Many meshs and types: 4 `TRIA3`, 2 `QUAD4`

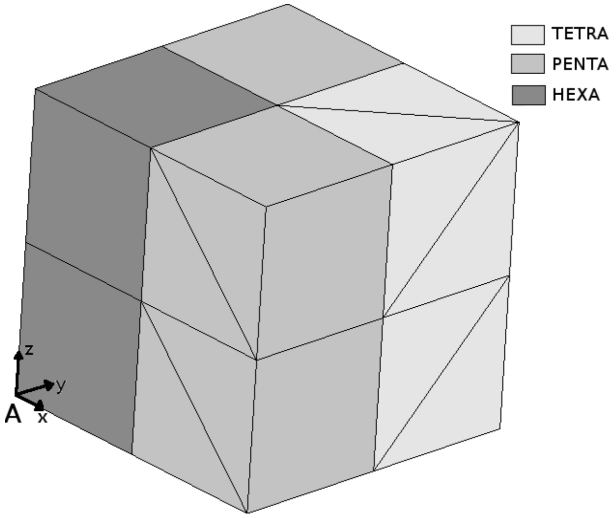
4.3 Sizes tested and results

Identification	Moments	Reference	*Aster AXIS*	*Aster AXIS_DIAG*	% difference
T node A	5	22.5	22.46	22.46	-0.19
T node A	15	57.8	58.35	58.35	0.95
T node A	60	79.1	78.84	78.84	-0.33
hy node A	15	0,594	0,603	0,603	1.5

5 Modeling C

5.1 Characteristics of modeling

Two calculations are carried out, one thermal and other mechanics, each one in modeling `3D`.



5.2 Characteristics of the grid

Many nodes: 116
Many meshs and types: 2 `HEXA20`, 8 `PENTA15`, 24 `TETRA10`

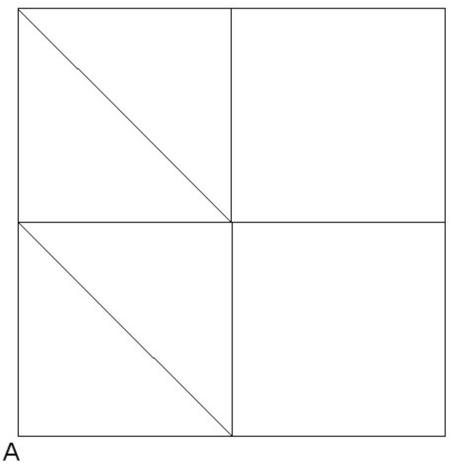
5.3 Sizes tested and results

Identification	**Moments**	**Reference**	***Aster 3D***	**% difference**
T node A	5	22.5	22.46	-0.19
T node A	15	57.8	58.35	0.95
T node A	60	79.1	78.84	-0.33
hy node A	15	0,594	0,603	1.5

6 Modeling D

6.1 Characteristics of modeling

Two calculations are carried out, one in modeling `AXIS` and the other `AXIS_DIAG`.



6.2 Characteristics of the grid

Many nodes: 23
Many meshs and types: 4 `TRIA6`, 2 `QUAD9`

6.3 Sizes tested and results

Identification	Moments	Reference	*Aster AXIS*	*Aster AXIS_DIAG*	% difference
T node A	5	22.5	22.46	22.46	-0.19
T node A	15	57.8	58.35	58.35	0.95
T node A	60	79.1	78.84	78.84	-0.33
hy node A	15	0,594	0,603	0,603	1.5

7 Summary of the results

The error obtained compared to the reference solution is about 1% with regard to the temperature and the hydration. Let us announce that with the problem was dealt with steps of relatively small times for the phenomenon of hydration which lasts several tens of hours. This refinement is necessary because of the explicit integration of the hydration.

The results with and without diagonnalisation of the matrix 'masses' thermal are identical because the phenomenon observed does not contain a very constraining transitional stage.