HSNA100 - Drying of a concrete enclosing wall

Summary:

This case test is intended to validate the calculation of the drying of the concrete, developed in the operator of nonlinear thermics of *Code_Aster*. The studied case corresponds to the simulated drying of the enclosure of Flamanville. The geometrical data and the characteristic materials result from the thesis of Laurent Granger "Behavior differed from the concrete in the enclosures from nuclear power plants" published by the Central Laboratory from the Highways Departments (1996, pages 185 to 204).

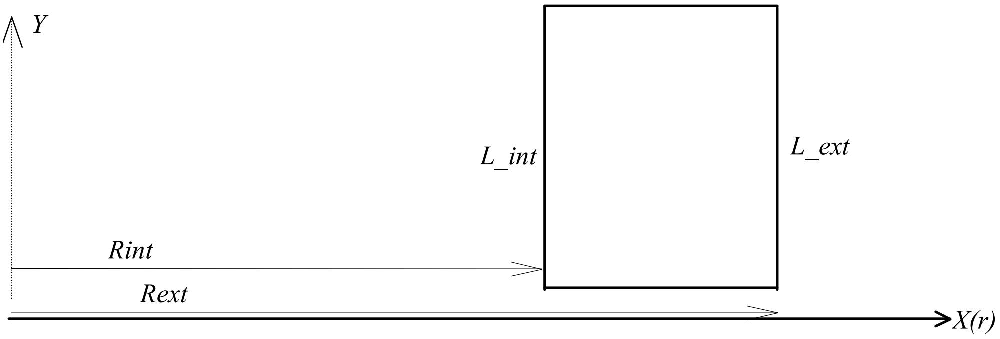
Drying is carried out by exchange with outside, on the walls internal and external of the wall, in axisymmetric modeling $2D$. It is carried out over one 54 years duration.

The coefficient of diffusion of drying depend on the temperature, the analysis is made up of the chaining of a thermal calculation and a calculation of drying. One carries out then a mechanical calculation of withdrawal in linear elasticity and plasticity Von Misès with an isotropic work hardening.

1 Problem of reference

1.1 Geometry

The enclosure is modelled on a height $\mathrm{Lint}=\mathrm{Lext}=1\,m$
Ray external of the enclosure: $Rext=23{,}5\,m$
Interior ray of the enclosure: $Rint=22{,}5\,m$



1.2 Material properties

For thermal calculation:

Thermal coefficient of diffusion process: $\lambda=80\,J/(h.cm.{}^\circ C)=2.22\,W/(m.{}^\circ C)$
Voluminal heat: $\rho C_p=2.4\,10^6\,J/m^3/{}^\circ C$

For the calculation of drying:

In the equation of drying:

$$\frac{dC}{dt}-\mathrm{div}\left[D(C,T)\,grad\,C\right]=0$$

the coefficient of diffusion D will be form recommended by Granger [bib1], [bib2]:

$$D(C,T)=A\exp(BC)\frac{T}{T_0}\exp\left[-\frac{Q_S}{R}\left(\frac{1}{T}-\frac{1}{T_0}\right)\right]$$

$$A=3.8\,10^{-13}\,m^2/s$$
$$B=0.05$$
$$T_0=0\,{}^\circ C$$
$$\frac{Q_S}{R}=4700\,K^{-1}$$

1.3 Boundary conditions and loadings

For thermal calculation:

A heat exchange is imposed on the walls interior and external of the enclosing wall (groups of meshs l_{int} and l_{ext}).
During the first five years, the outside temperature is of $15°C$ on each wall:
$T_{\text{int}}=T_{\text{ext}}=15°C$
From the fifth year, the outside temperature interns master key with $35°C$:
$T_{\text{int}}=35°C$ and $T_{\text{ext}}=15°C$

The internal wall is regarded as non-ventilated and its coefficient of exchange is of $h_{\text{int}}=4\frac{W}{m^2.°C}$.

The external wall is regarded as ventilated and its coefficient of exchange is of $h_{\text{ext}}=6\frac{W}{m^2.°C}$.

(page 136 in [bib1]).

In practice, the scales of time of drying being much higher than those of thermics, one can consider that thermal balance is quasi immediate. Calculation is carried out in linear thermics.

For the calculation of drying:

The boundary conditions are expressed in term of normal flow of moisture on the walls internal and external of the enclosure (groups of meshs l_{int} and l_{ext}). The option is used `FLUX_NL` of the operator `AFFE_CHAR_THER_F` . Normal flow is expressed generally, in a calculation of drying, according to the initial concentration C_0 , concentration to 50 % of moisture C_{50} and of the external concentration C_{ext} , in the form:

$$w=-D(C,T)\frac{\partial C}{\partial n}=\frac{0.5\beta}{(C_0-C_{50})^2}\left[C-(2C_0-C_{ext})\right](C-C_{ext})$$

with

$\beta=3.41557.10^{-6}\frac{l}{m^2.s}$ (page 181 in [bib1])

The data retained in the case of the enclosure of Flamanville are the following ones:
$C_0=105.7\,l/m^3$ and $C_{50}=57.5\,l/m^3$ (page 194 in [bib1])

On the interior face:

From 0 to 5 years *,* $C_{ext}=69.1\,l/m^3$ Value for 60% of moisture

of *5 with 54 years,* $C_{ext}=51.6\,l/m^3$ Value for 45% of moisture

On the outside:

$C_{ext}=69.1\,l/m^3$

The calculation of drying is carried out in nonlinear thermics, by chaining with linear thermal calculation.

1.4 Initial conditions

The initial conditions are consisted the initial temperature, which one takes with $15°C$, and initial water concentration, which is worth $C_0=105.7\,l/m^3$

2 Reference solution

2.1 Method of calculating used for the reference solution

The reference solution is consisted the calculation carried out with a similar modeling by L. Granger, within the framework of its thesis [bib1]. The case test relates to the calculation carried out with the experimental data corresponding to the enclosure of Flamanville. The implementation and the results are described there pages 185 to 204.
Drying is carried out over 54 years, by taking account of the change of boundary conditions at the time of the fifth year.

2.2 Results of reference

Water concentration in the thickness of the enclosure, at the end of 5.15, and 54 years.

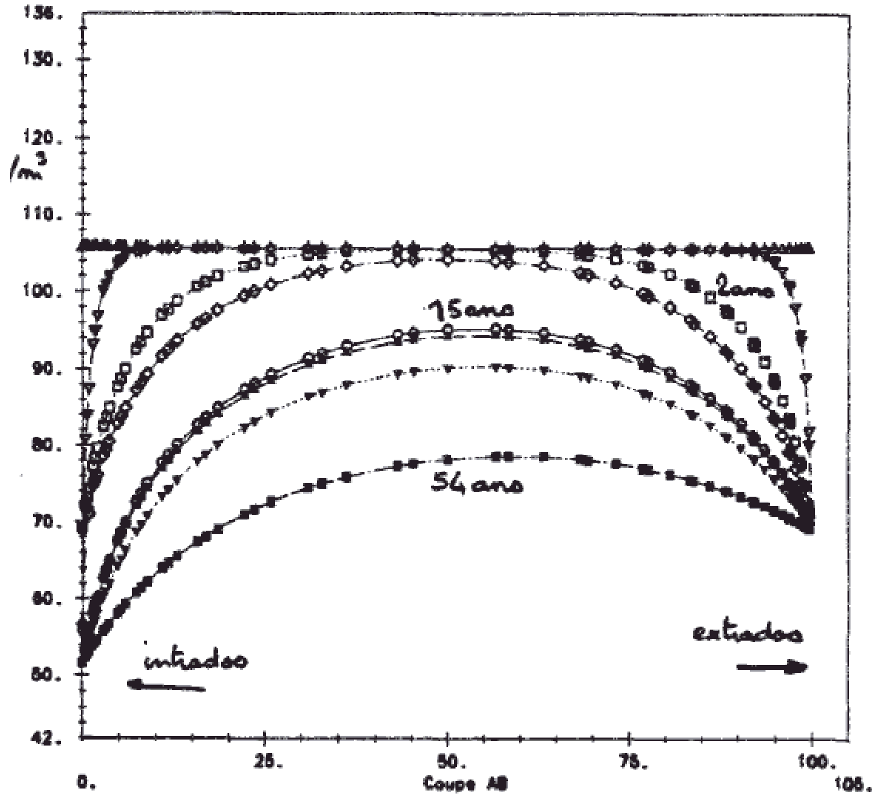


Figure 1: Water concentration according to a cut for various moments (page 204 [bib1])

2.3 Uncertainty on the solution

One does not have that water concentrations calculated within the framework the thesis of Laurent Granger, without precise numerical data. The results of references are directly extracted from Figure 1. The uncertainty of the solution is more impotante in skin (where the points are superimposed) that in heart.

2.4 Bibliographical references

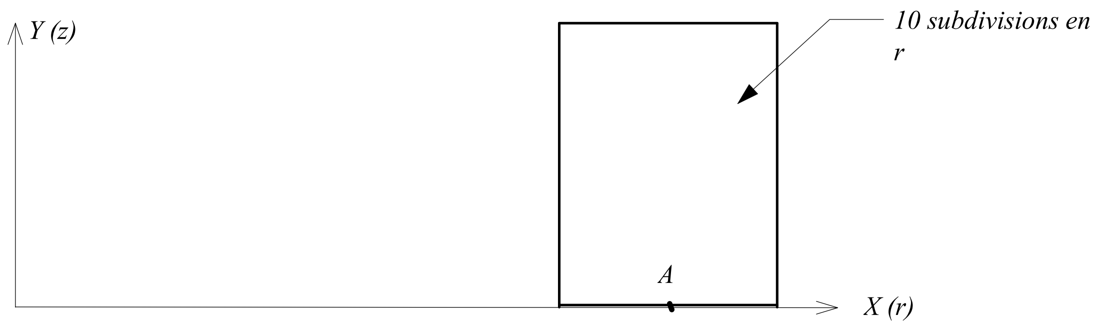
1. L. GRANGER: "Behavior differed from the concrete in the enclosures of nuclear power plants" published by the Central Laboratory from the Highways Departments (1996).

2. G. DEBRUYNE, B. CIREE: “Modeling of thermohydration, the drying and the withdrawal of the concrete”, handbook of Reference *Code_Aster* , [R7.01.12] (2001).

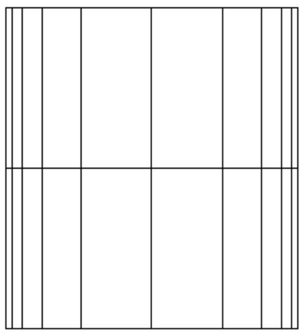
3 Modeling A

3.1 Characteristics of modeling

It is about an axisymmetric modeling.
Cutting in 10 elements of variable size on the thickness, 2 elements on the height.



3.2 Characteristics of the grid



Many nodes: 55
Number of meshs and type: 20 `QUAD4`

3.3 Sizes tested and results

The water concentration is tested on 10 nodes distributed in the thickness at three moments (5, 15 and 54 years):
At 5 years:

X	Reference	*Aster*	% difference
22.50	67.68	69.40	-2.53
22.54	80.91	81.15	-0.29
22.60	89.69	90.61	-1.02
22.68	97.80	97.96	-0.16
22.81	102.21	102.99	-0.77
23.00	104.00	105.02	-0.98
23.19	102.00	102.95	-0.94
23.32	97.80	97.89	-0.09
23.40	90.18	90.53	-0.39
23.46	81.00	81.10	-0.12
23.50	71.20	69.36	2.58

At 15 years:

X	Reference	*Aster*	% difference
22.50	54.2257	51.78	4.50
22.54	65.2	64.55	1.00
22.60	75.4576	74.96	0.66
22.68	84.9649	83.71	1.47
22.81	91.4	90.73	0.73
23.00	95.2	94.89	0.33
23.19	93.55	93.73	-0.19
23.32	89.3776	89.22	0.18
23.40	82.8	83.13	-0.40
23.46	76.3516	76.30	0.07
23.50	70.0603	69.28	1.12

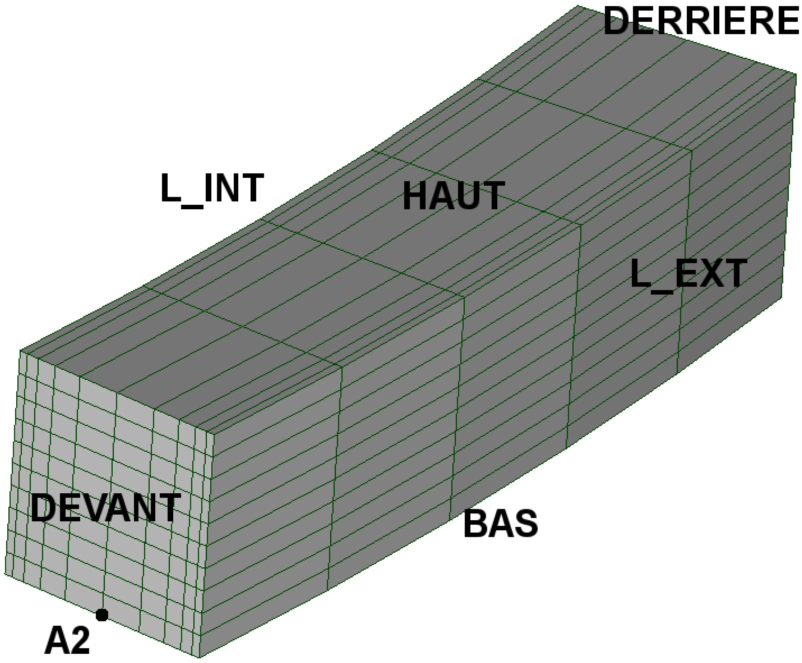
At 54 years:

X	Reference	*Aster*	% difference
22.50	51.6	51.66	-0.11
22.54	56.8903	56.46	0.75
22.60	62.4	61.98	0.68
22.68	69.1059	67.83	1.84
22.81	74.4781	73.40	1.44
23.00	78.3688	77.45	1.17
23.19	77.8487	77.71	0.18
23.32	75.9533	75.73	0.29
23.40	73.1186	73.24	-0.17
23.46	70,815	70.96	-0.21
23.50	68.8035	69.15	-0.50

4 Modeling B

4.1 Characteristics of modeling

It is about a modeling 3D



4.2 Characteristics of the grid

Many nodes: 726.
The voluminal meshs are hexahedral meshs 500 HEXA8.

4.3 Sizes tested and results

The water concentration is tested on 10 nodes distributed in the thickness at three moments (5, 15 and 54 years):
At 5 years:

X	Reference	*Aster*	% difference
22.50	67.68	69.40	-2.53
22.54	80.91	81.15	-0.29
22.60	89.69	90.61	-1.02
22.68	97.80	97.95	-0.16
22.81	102.21	102.99	-0.77
23.00	104.00	105.02	-0.98
23.19	102.00	102.95	-0.93
23.32	97.80	97.89	-0.09
23.40	90.18	90.53	-0.39
23.46	81.00	81.10	-0.12
23.50	71.20	69.36	2.58

At 15 years:

X	Reference	*Aster*	% difference
22.50	54.2257	51.78	4.50

22.54	65.2	64.55	1.00
22.60	75.4576	74.96	0.67
22.68	84.9649	83.71	1.48
22.81	91.4	90.73	0.74
23.00	95.2	94.88	0.33
23.19	93.55	93.73	-0.19
23.32	89.3776	89.22	0.18
23.40	82.8	83.13	-0.40
23.46	76.3516	76.30	0.07
23.50	70.0603	69.28	1.12

At 54 years:

X	**Reference**	***Aster***	**% difference**
22.50	51.6	51.66	-0.11
22.54	56.8903	56.46	0.75
22.60	62.4	61.97	0.68
22.68	69.1059	67.83	1.84
22.81	74.4781	73.40	1.45
23.00	78.3688	77.45	1.18
23.19	77.8487	77.71	0.18
23.32	75.9533	75.73	0.30
23.40	73.1186	73.24	-0.16
23.46	70,815	70.96	-0.21
23.50	68.8035	69.15	-0.50

5 Summary of the results

The precision of the results is lower than 5% approximately for the water concentration compared to the reference solution which one does not know the proper precision.