HSNA100 - Drying of Summarized a concrete enclosing wall

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This case test is intended to validate the computation of the drying of the concrete, developed in the operator of nonlinear thermal 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 from 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).

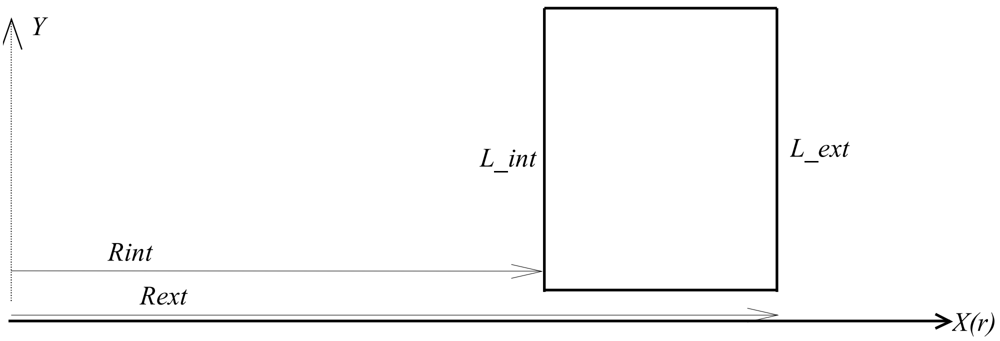
Drying is carried out by exchange with outside, on the walls internal and external of the wall, in axisymmetric modelization $2D$. It is carried out over a 54 years period.

The coefficient of diffusion of drying depend on the temperature, the analysis is made up of the sequence of a thermal computation and a computation of drying. One carries out then a mechanical computation of shrinkage in linear elasticity and plasticity Von Mises with an isotropic hardening.

1 Problem of reference

1.1 Geometry

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



1.2 Material properties

For thermal computation:

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

For the computation 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]:

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

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

1.3 Boundary conditions and loadings

For thermal computation:

A heat exchange is imposed on the walls interior and external of the enclosing wall (mesh groups 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 heat exchange is of $h_{\text{int}}=4\dfrac{W}{m^2.°C}$.

The external wall is regarded as ventilated and its coefficient of heat exchange is of $h_{\text{ext}}=6\dfrac{W}{m^2.°C}$.
(page 136 in [bib1]).

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

For the computation of drying:

The boundary conditions are expressed in term of normal flux of moisture on the walls internal and external of the enclosure (mesh groups l_{int} and l_{ext}). One uses option `FLUX_NL` of operator `AFFE_CHAR_THER_F` . The normal flux is expressed generally, in a computation of drying, according to the initial concentration C_0 , of the 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

$\beta=3.41557.10^{-6}\dfrac{l}{m^2.s}$ (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
from *5 to 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 computation of drying is carried out in nonlinear thermal, by sequence with linear thermal computation.

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 Méthode de calcul used for the reference solution

the reference solution is consisted the computation carried out with a similar modelization by L. Granger, in the frame of his thesis [bib1]. The case test relates to the computation 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.

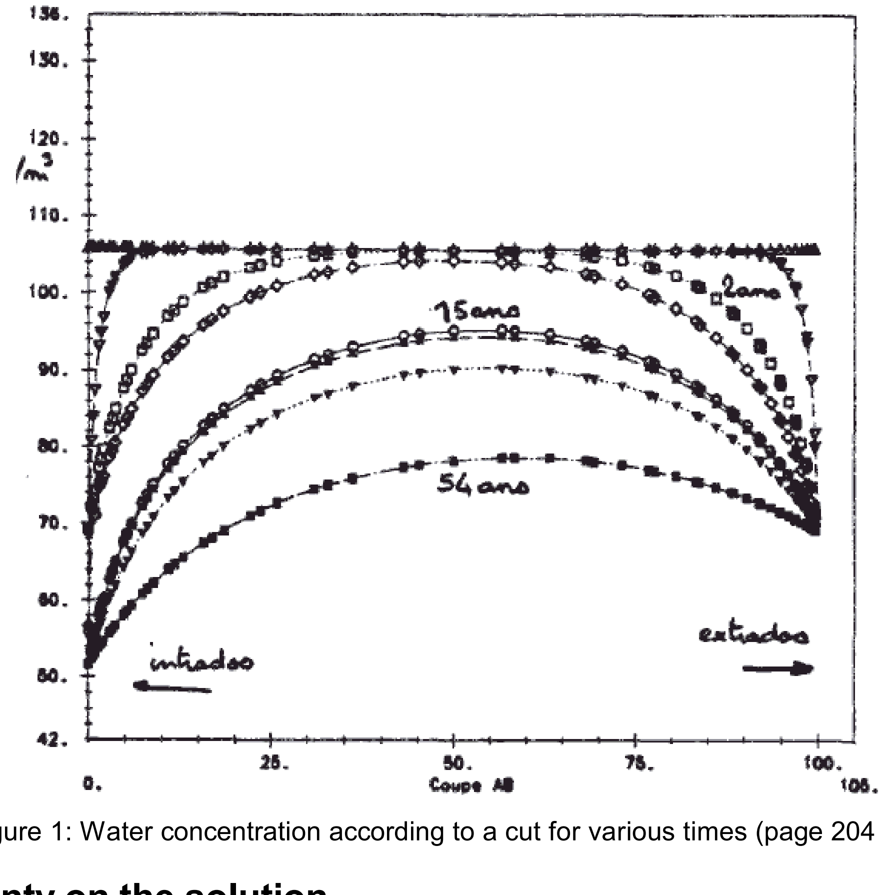


Figure 1: Water concentration according to a cut for various times (page 204 [bib1])

2.3 Uncertainty on the solution

One has only the water concentrations calculated in the frame of 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

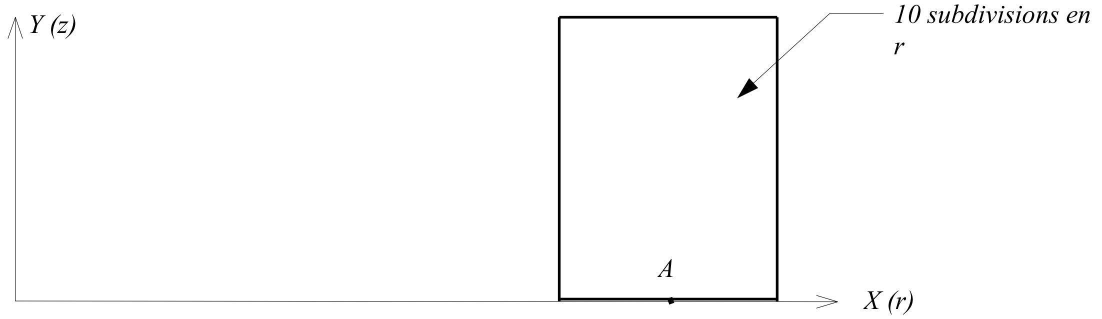
1.L. GRANGER: “Behavior differed from the concrete in the enclosures of nuclear power plants” published by the Central Laboratory from the Highways Departments (1996).

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

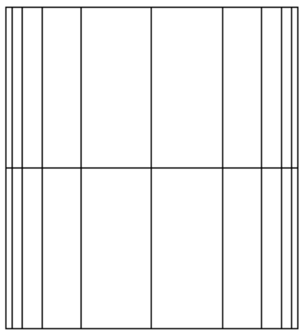
3 Modelization A

3.1 Characteristic of the modelization

It acts of an axisymmetric modelization.
Cutting in 10 elements of variable size on the thickness, 2 elements on the height.



3.2 Characteristics of the mesh



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

3.3 Quantities tested and results

the water concentration is tested on 10 nodes distributed in the thickness at three times (5, 15 and 54 years):
A5 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

A 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

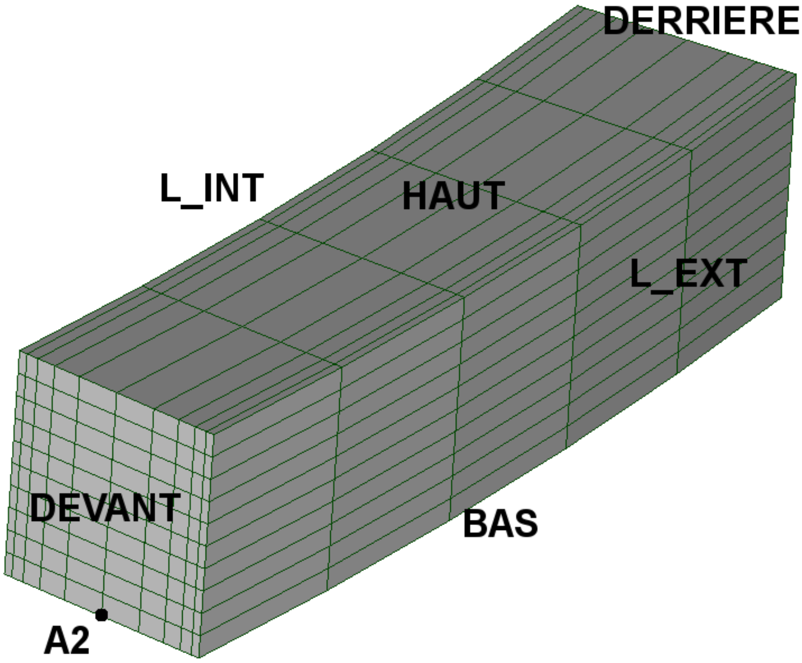
A 54 years:

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 Modelization B

4.1 Characteristic of the modelization

It acts of a modelization 3D



4.2 Characteristic of the mesh

Many nodes: 726.
The meshes voluminal ones are meshes hexahedral 500 HEXA8.

4.3 Quantities tested and results

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

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23.50	68.8035	69.15	-0.50

5 Summary of the results

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