HSNA102 - Validation of the models of drying on a cylindrical Summarized concrete test-tube

:

This case test is intended to validate the computation of the drying of the concrete, developed in the operator of nonlinear thermal of *the Code_Aster*. One tests here the various models of diffusion available in *Code_Aster*, namely `SECH_GRANGER`, `SECH_MENSI`, `SECH_BAZANT` and `SECH_NAPPE`. The possible dependence with the temperature of the models is however not tested.

It is about an axisymmetric case test where the water concentration is applied directly to the external wall. The results are compared with a numerical resolution of the equations using Scilab.

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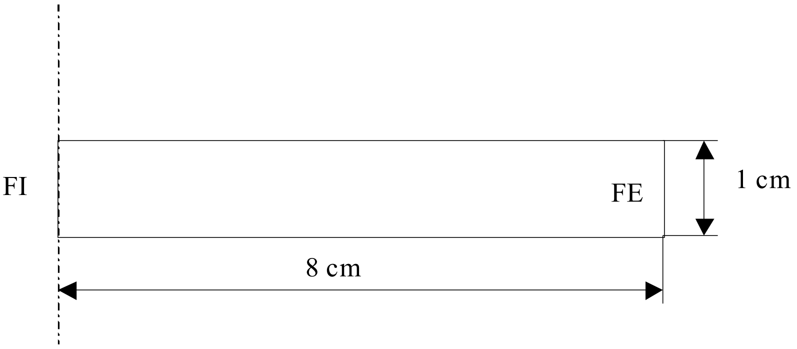
1 Problem of reference

1.1 Geometry

One models a cylindrical slice of test-tube of diameter $160\,mm$.



1.2 Material properties

Each modelization makes it possible to validate a coefficient of diffusion D, namely:

- modelization a: model of Mensi $D(C) = A\exp(BC)$
- modelization b: model of Granger $D(C,T) = A\exp(BC)\dfrac{T}{T_0}\exp\left[-\dfrac{Q_s}{R}\left(\dfrac{1}{T}-\dfrac{1}{T_0}\right)\right]$
- modelization C: definition of D in the form of three-dimensions function
- modelization D: model of Bazant $D(h) = D_1\left(\alpha + \dfrac{1-\alpha}{1+\left(\dfrac{1-h(C)}{1-0.75}\right)^n}\right)$

the coefficients used are those recommended by Granger in its thesis [bib1]:

`SECH_MENSI :`

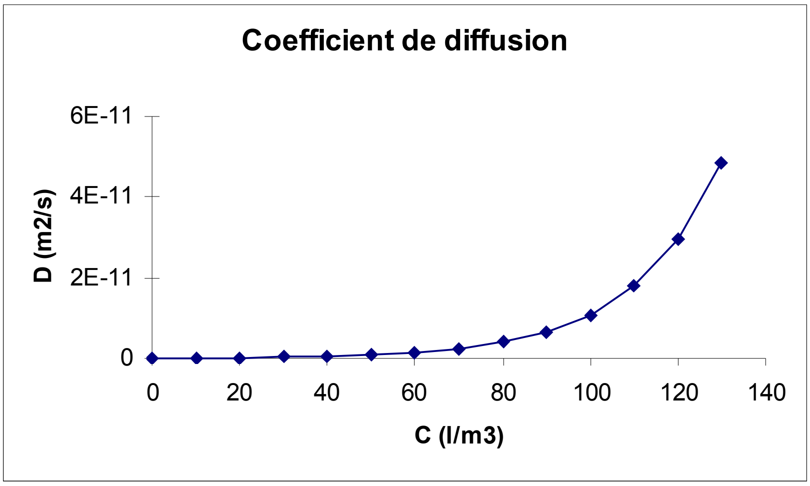
$A=0.74\,10^{-13} m^2/s$
$B=0.05$

`SECH_GRANGER`

$A=0.74\,10^{-13} m^2/s$
$B=0.05$
$T_0=293°K$
$Q_s/R=4700\,K^{-1}$

`SECH_NAPPE`

One returns in the form of three-dimensions function the model of Mensi



`SECH_BAZANT`

$D1=3.0\,10^{-10} m^2/s$
$\alpha=0.04$
$n=6$

$$h=1-0.5\left(\frac{C-C_0}{C_0-C_{eq}}\right)^2$$ with $C_0=128.8\,l/m^3$ and $C_{eq}=58.8\,l/m^3$

1.3 Boundary conditions and loadings

The computation of drying is carried out over a 5 years period

- the temperature remains uniform and is worth $20°C$
- one applies to FE : $C_{eq}=58.8\,l/m^3$

1.4 Initial conditions

the initial conditions are consisted the initial temperature, which one takes with $20°C$, and initial water concentration, which is worth $C_0=128.8\,l/m^3$.

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2 Reference solution

2.1 Method of calculating used for the reference solution

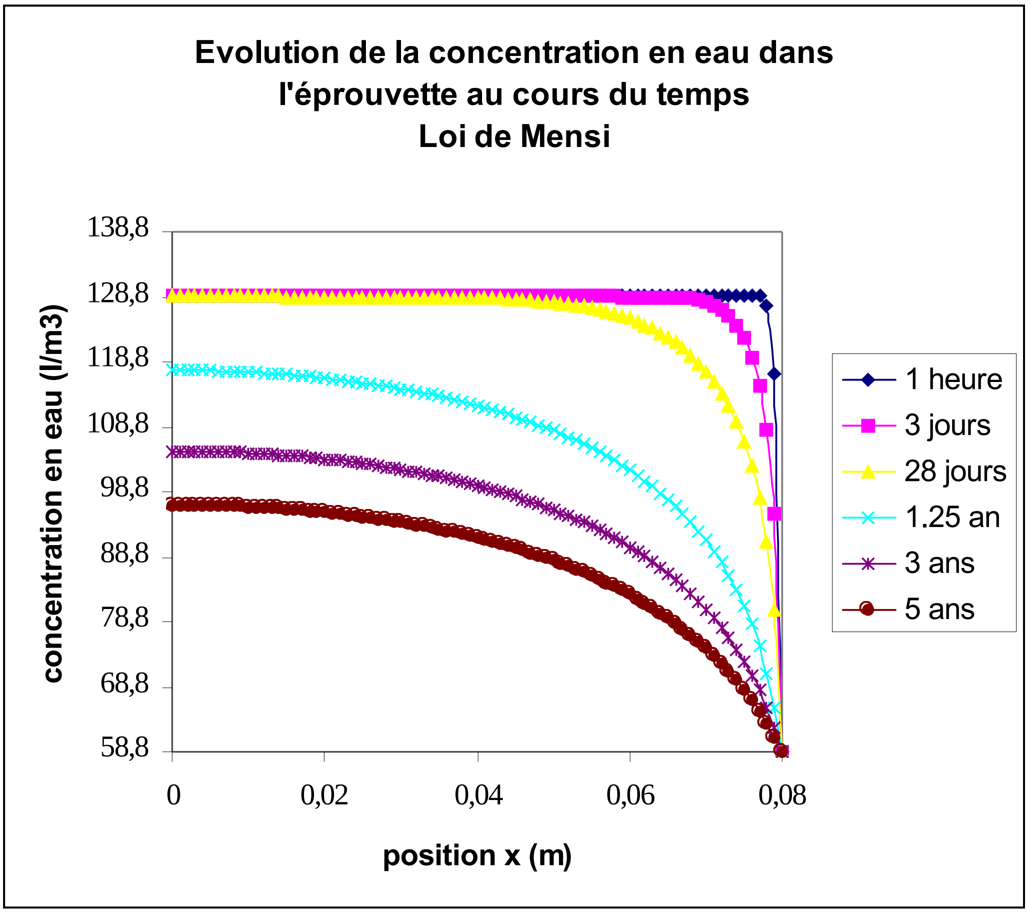
the 2 reference solutions are obtained by resolution of the equation of drying by finite differences using Scilab. The command file is given in appendix to possibly be able to test new models.
The spatial discretization is the same one as for Aster with knowing of meshes of $1\,mm$. The temporal discretization is 3600 seconds for the equation of Mensi, and 60 seconds for the equation of Bazant.

2.2 Results of reference

One is interested in the water concentration in the test-tube after 1:00, 3j, 28j, 1.25 year, 3 years and 5 years. The evolution of the profiles obtained with Scilab for the model of Mensi and the model of Bazant is visible on [Figure 2.2-a] and [Figure 2.2-b].

Note:

The comparison between the solutions Scilab and Aster is visible in [§Annexe 2]: one shows the concentrations obtained in the test-tube after 1 a.m. and 5 years. One thus checks the good correlation excluded for the solution obtained with Aster for the model of Mensi at the end of one hour when one observes an oscillation which makes much think of a violation of the principle of the maximum observed in thermal (cf [bib2]). It would be thus interesting to be able to use the lumped elements when one solves the equation of drying even if the phenomenon is accentuated here because of the boundary conditions, since one directly imposes the water concentration instead of imposing a flux [bib3].



Appear 2.2-a: Scilab solution - model of Mensi

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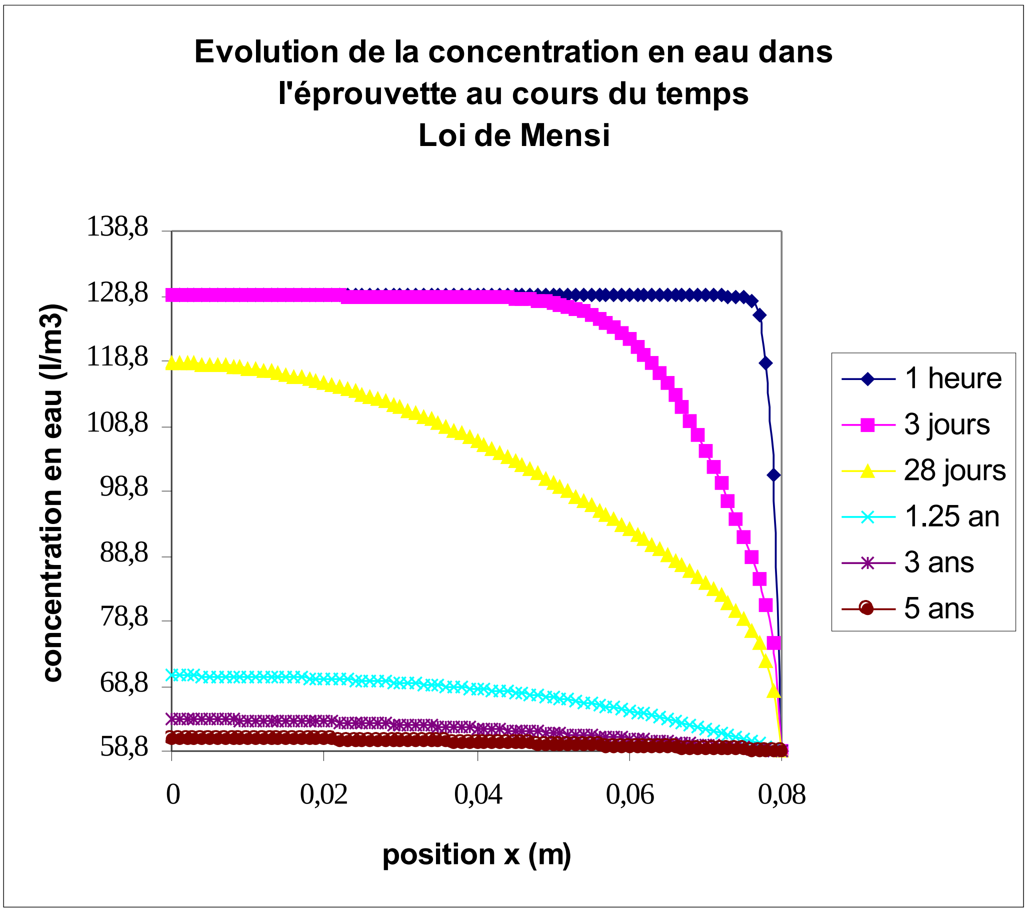

Appears 2.2-a: Scilab solution - model of Bazant

`the TEST_RESU` are carried out for 6 characteristic times with the X-coordinates $x=0\text{mm}$, $x=40\,mm$ and $x=60\,mm$.

2.3 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) S. MICHEL-PONNNELLE, A. RAZAKANAIVO: “I7-01-08 Project: Quality of the Studies in Mechanics of Solids – Stage n°4: study of the finite elements”, EDF Notes: HT - 64/02/007/A, June 2002

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

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3 Modelization A

3.1 Characteristic of the modelization

One uses the model of diffusion of Mensi.

3.2 Characteristics of the mesh

the test-tube with a grid using 80 `QUAD4` is regularly distributed. There is only one element in the height.

Many nodes: 162
Number of meshes and type: 80 `QUAD4`

3.3 Characteristics of the temporal discretization

Initial Time (s)	Final moment (s)	Many time step
0	3600	10
3600	259.200	10.259.200
	2.419.200	10
2.419.200	39.420.000	10
39.420.000	94.608.000	10
94.608.000	1 57.680.000	10

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3.4 Quantities tested and Concentration

results out of water with point: $x=0.0$

Identification	**backward differences**	***Reference***	**% Aster**
1 hour	128.80	128.80	2.21 10-14
after 3 days	128.80	128.80	-2.21 10-14
after 28 days	128.80	128.80	-3.67 10-5
after 1.25 year	117.49	117.76	0.231
after 3 years	105.06	105.38	0.307
after 5 years	96.77	97.09	0.332

water Concentration to point: $x=0.04$

Identification	**backward differences**	***Reference***	**% Aster**
1 hour	128.80	128.80	1.31 10-13
after 3 days	128.80	128.80	-1.77 10-13
after 28 days	128.61	128.66	0.038
after 1.25 year	117.74	112.35	0.543
after 3 years	99.43	100.06	0.634
after 5 years	91.39	91.99	0.661

water Concentration to point: $x=0.06$

Identification	**backward differences**	***Reference***	**% Aster**
1 hour	128.80	128.80	2.53 10-11
after 3 days	128.80	128.80	0.002
after 28 days	124.98	125.67	0.552
after 1.25 year	101.32	102.42	1.089
after 3 years	89.60	90.64	1.158
after 5 years	82.33	83.27	1.140

3.5 Comments

One checks here that the made mistake is weak since lower than 1.5% , which is completely correct being given the relatively coarse discretization temporal used, in particular at the end of the computation.

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4 Modelization B

4.1 Characteristic of the modelization

One uses the model of diffusion of Granger

4.2 Characteristics of the mesh

the test-tube with a grid using 80 `QUAD4` is regularly distributed. There is only one element in the height.

Many nodes: 162
Number of meshes and type: 80 `QUAD4`

4.3 Characteristics of the temporal discretization

Initial Time (s)	Final moment (s)	Many time step
0	3600	10
3600	259.200	10.259.200
	2.419.200	10
2.419.200	39.420.000	10
39.420.000	94.608.000	10
94.608.000	1 57.680.000	10

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4.4 Quantities tested and Concentration

results out of water with point: $x=0.0$

Identification	**backward differences**	***Reference***	**% Aster**
1 hour	128.80	128.80	2.21 10-14
after 3 days	128.80	128.80	-2.21 10-14
after 28 days	128.80	128.80	-3.67 10-5
after 1.25 year	117.49	117.76	0.231
after 3 years	105.06	105.38	0.307
after 5 years	96.77	97.09	0.332

water Concentration to point: $x=0.04$

Identification	**backward differences**	***Reference***	**% Aster**
1 hour	128.80	128.80	1.31 10-13
after 3 days	128.80	128.80	-1.77 10-13
after 28 days	128.61	128.66	0.038
after 1.25 year	117.74	112.35	0.543
after 3 years	99.43	100.06	0.634
after 5 years	91.39	91.99	0.661

water Concentration to point: $x=0.06$

Identification	**backward differences**	***Reference***	**% Aster**
1 hour	128.80	128.80	2.53 10-11
after 3 days	128.80	128.80	0.002
after 28 days	124.98	125.67	0.552
after 1.25 year	101.32	102.42	1.089
after 3 years	89.60	90.64	1.158
after 5 years	82.33	83.27	1.140

4.5 Comments

One finds the same solution exactly as the model of Mensi.

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5 Modelization C

5.1 Characteristic of the modelization

One uses the model of diffusion `SECH_NAPPE`, for which one returns simply the model of diffusion of Mensi.

5.2 Characteristics of the mesh

the test-tube with a grid using 80 `QUAD4` is regularly distributed. There is only one element in the height.

Many nodes: 162
Number of meshes and type: 80 `QUAD4`

5.3 Characteristics of the temporal discretization

Initial Time (s)	Final moment (s)	Many time step
0	3600	10
3600	259.200	10.259.200
	2.419.200	10
2.419.200	39.420.000	10
39.420.000	94.608.000	10
94.608.000	1 57.680.000	10

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6 Results of the modelization C

6.1 Values tested

water Concentration with point: $x=0.0$

Identification	backward differences	*Reference*	$\%$ Aster
1 hour	128.80	128.80	1.32 10-13
after 3 days	128.80	128.80	8.83 10-14
after 28 days	128.80	128.80	-4.35 10-5
after 1.25 year	117.49	117.51	0.012
after 3 years	105.06	105.04	-0.021
after 5 years	96.77	96.73	-0.037

water Concentration to point: $x=0.04$

Identification	backward differences	*Reference*	$\%$ Aster
1 hour	128.80	128.80	1.32 10-13
after 3 days	128.80	128.80	-4.41 10-13
after 28 days	128.61	128.65	0.029
after 1.25 year	117.74	112.11	0.328
after 3 years	99.43	99.74	0.318
after 5 years	91.39	91.68	0.319

water Concentration to point: $x=0.06$

Identification	backward differences	*Reference*	$\%$ Aster
1 hour	128.80	128.80	2.45 10-11
after 3 days	128.80	128.80	0.002
after 28 days	124.98	125.57	0.471
after 1.25 year	101.32	102.18	0.856
after 3 years	89.60	90.35	0.843
after 5 years	82.33	82.99	0.798

6.2 Comments

One sees here that the error is lower than 1% .

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7 Modelization D

7.1 Characteristic of the modelization

One uses the model of diffusion of Bazant.

7.2 Characteristics of the mesh

the test-tube with a grid using 80 `QUAD4` is regularly distributed. There is only one element in the height.

Many nodes: 162
Number of meshes and type: 80 `QUAD4`

7.3 Characteristics of the temporal discretization

Initial Time (s)	Final moment (s)	Many time step
0	3600	10
3600	259.200	20.259.200
	2.419.200	20
2.419.200	39.420.000	20
39.420.000	94.608.000	10
94.608.000	1 57.680.000	10

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8 Results of the modelization D

8.1 Values tested

water Concentration with point: $x=0.0$

Identification	**backward differences**	***Reference***	$\%$ **Aster**
1 hour	128.80	128.80	0.
after 3 days	128.80	128.80	-3.70 10-7
after 28 days	118.42	118.63	0.175
after 1.25 year	70.36	70.51	2.227
after 3 years	63.63	63.76	0.210
after 5 years	60.67	60.73	0.102

water Concentration to point: $x=0.04$

Identification	**backward differences**	***Reference***	$\%$ **Aster**
1 hour	128.80	128.80	-2.21 10-14
after 3 days	128.66	128.70	0.031
after 28 days	105.89	106.80	0.853
after 1.25 year	68.25	68.53	0.415
after 3 years	62.24	62.40	0.259
after 5 years	60.06	60.13	0.119

water Concentration to point: $x=0.06$

Identification	**backward differences**	***Reference***	$\%$ **Aster**
1 hour	128.80	128.80	-1.18 10-11
after 3 days	120.99	122.47	1.225
after 28 days	92.11	93.21	1.192
after 1.25 year	65.16	64.80	0.563
after 3 years	60.62	60.76	0.234
after 5 years	59.43	59.49	0.097

8.2 Comments

One checks here that the made mistake is weak since lower than 1.5% .

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9 Summary of the results

For all the modelizations, one obtains a difference between the solution SCILAB and the solution *Code_Aster* lower than $1.5\,\%$ what makes it possible to validate the model installation of various of drying in the code. Let us note simply that one observes a violation of the principle of the maximum at the beginning of simulation with Aster for the model of Mensi. This can be explained (by analogy with the thermal) by the “hydrous shock” important due like imposing the boundary conditions (imposed water concentration). This problem should be able to be solved by the use of the lumped elements in the same way that in thermal.

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Annexe 1 Command file Scilab

```
Main.sci: getf
("/home/xxxx/librairie.sci"); //PARAMETERS
OF Computational simulation ////
discretization
of the width x0 =
0.08; X = [
- 0.080:0.001: +0.080]; [n1 N2] = size (X); //water content
initial Cinit
= 128.8; Ci =
Cinit*ones (1, N2); //boundary conditions
with 50%HR CL =
[58.8 58.8];. Ci (1)
= CL (1); Ci ($) = CL (2); Ci_bazant
= Ci; //time step
dt =
60; //[S] //coefficients
of the model of Bazant D1 =
3.0E-10; //[m2/s] has = 0.04
; N = 6
; TMAX
=                                    5;                                    //years
//___________________________________________________________________
////
COMPUTATIONAL SIMULATION
//J
= 0
; u=file
("open", "resultat_g", "unknown"); for year
= 0: TMAX, year
 for day
  = 0:364, for hour
  = 0:23, times
   = 0; for minute
    = 0:59, D_bazant
      = diffusion_bazant (D1, has, N, Cinit, 58.8, Ci_bazant, 293,293*ones (Ci),
4700); Ci_bazant
    = linear_drying (D_bazant, Ci_bazant, CL, dt, X, "whodunnit"); yew ((
    year == 0 & day  == 0 & hour   == 1 & times == 0) | … (year
        == 0 & day  == 3 & hour   == 0 & times == 0) | … (year
        == 0 & day  == 28 &  hour == 0 & times == 0) | … (year
        == 1 & day  == 91 &  hour == 0 & times == 0) | … (year
        == 3 & day  == 0 & hour   == 0 & times == 0) | … (year
        == 5 & day  == 0 & hour   == 0 & times == 0)) then, year
       , day, hour t=81:
       1:161; for tk
       =t, fprintf
         (U, "%6.3f %6.3f", X (tk), Ci_bazant (tk)) ; end,
       end,
     //yew end,
   //for time end,
  //for hour end,
 //for end day,
//for year slips by (

"closed", U); Librairie.sci
```

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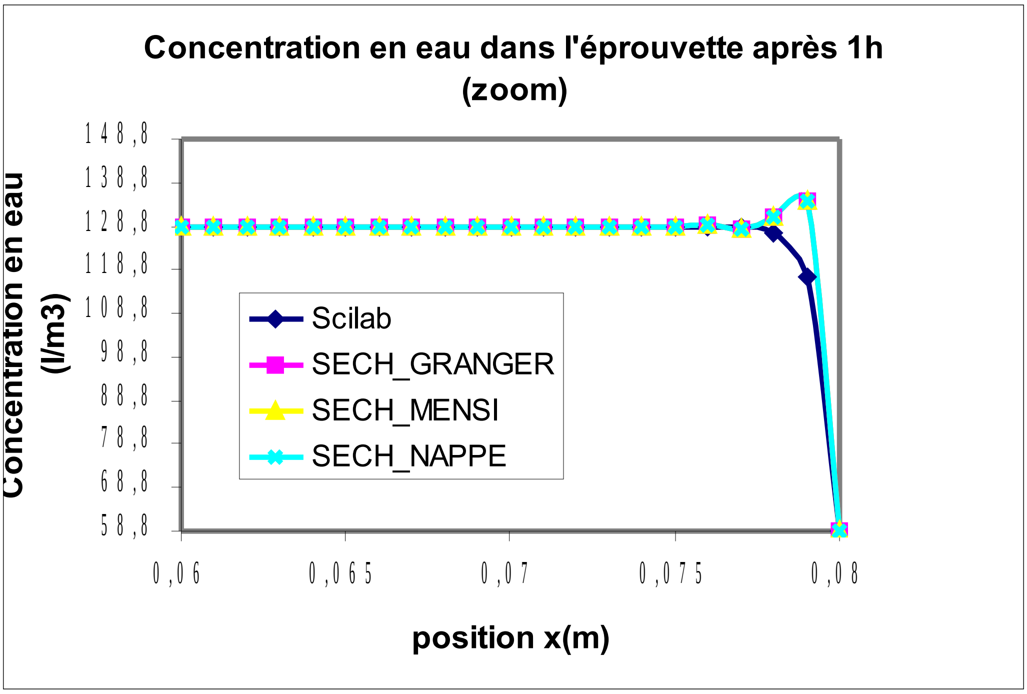
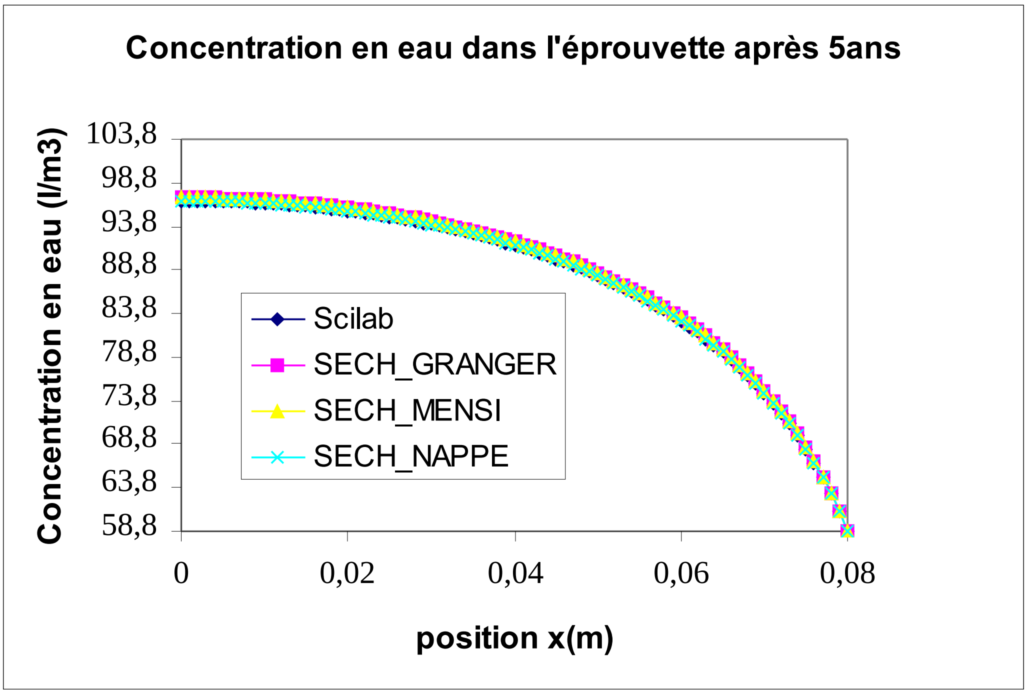
```
: ______
 _______________________________________________________////NONLINEAR

COEFFICIENT OF DIFFUSION FOR the DRYING OF the BETON //LOI OF
MENSI D (C) = a.exp (b.C) //THERMIC ACTION
D (C, T) = D (C, T0). (T/T0) .EXP [- Q/R* (1/T-1/T0)] ////has coefficient

     of the model of Mensi //B coefficient
     of the model of Mensi //C vector
of      the water contents [-] //T0 reference temperature
    [K] //T vector
of      the temperatures [K] //Q_R Q/R
(being worth  4700 K) function D
= diffusion_mensi (has, B, C, T0, T, Q_R), D = a*ones (
  C).*exp (b*C); D = D.* (T./
  (T0*ones (T))) ; D = D.*exp (
  Q_R* ((ones (T). /T0) - (ones (T). /T))) ; endfunction
, ////___
_
_______________________________________________________////NONLINEAR

COEFFICIENT OF DIFFUSION FOR the DRYING OF the BETON //LOI OF BAZANT
//THERMIC ACTION
D (C, T) = D (C, T0). (T/T0) .EXP [- Q/R* (1/T-1/T0)] ////D1
coefficient
    of the model of Bazant //has coefficient
     of the model of Bazant (alpha) C //N
     coefficient of the model of Bazant //C0
water content     with 100%HR //Cext
water content   of the surrounding medium //vector
of      the water contents [-] //T0 reference temperature
    [K] //T vector
of      the temperatures [K] //Q_R Q/R
(being worth  4700 K-1) function D
= diffusion_bazant (D1, has, N, C0, Cext, C, T0, T, Q_R), H = ones (C)
  - 0.5* ((C-C0*ones (C))/(Cext-C0))** 2; D = (((1-a)
  *ones (C). /(ones (C)+ (4 ** N) * (ones (C) - H) ** N))+a*ones (C)) *D1; D = D.*
(T./
  (T0*ones (T))) ; D = D.*exp (
  Q_R* ((ones (T). /T0) - (ones (T). /T))) ; endfunction
, //______
_______________________________________________________////DIFFUSION

//Resolution
by the method of the finite differences ////D vector

of      the coefficients of diffusion //Ci vector
of     the water contents at time J [-] //CL boundary condition
    in xmin and xmax of the type Dirichlet (C=C0) //dt time step
    [S] //X vector
of      the X-coordinates [m] polar //mode_
/cartesien  function cf
= linear_drying (D, Ci, CL, dt, X, mode_), [n1, N2] = size
  (Ci); dx_ = zeros
  (1, N2-2); dx_ (1: $)   = (X (3: $) - X (1: $-2))*0.5; //Cf_ = (
D*dt  * (ones (dx_). /(dx_ ** 2)). * (Ci (3: $) - 2*Ci (2: $-1) +Ci (1: $-2)))+Ci
(2: $-1); dx3 = ((
  …     (X (2: $ -                     1) - X
```

```
               (1: $-2)). *… (X (3: $) - X
               (1: $-2))  …). *…   (X
              (3: $)                    - X (2
               : $-1)) …); d2     C_dx
            2 = 2
  * (Ci (3: $). * (X (2: $ -  1) - X (1: $-2))… here (2: $-1).
               * (X (3: $) - X (1: $-2)  )… +Ci (1: $-2).
               * (X (3: $) - X (2: $-1)  )); d2C_dx2 = D
  2C_dx2. /dx3; yew (mode_ =
  = "whodunnit") then, dC_dx = (Ci
    (3: $). * (X (2: $ -  1) - X (1: $-2)) ** 2… here (1: $-2).
            * (X (3: $) - X (2: $-1)  ) ** 2); //here (2: $
- 1).              * ((X (2: $-1) - X (1: $-2)) ** 2 - (X (3: $) - X (2: $-1))  **
2)… dD_dx = (
    D (3: $). * (  X (2: $ -  1) - X (1: $-2)) ** 2… - D (1: $-2).
            * (X (3: $) - X (2: $-1)  ) ** 2); //- D (2: $
- 1).              * ((X (2: $-1) - X (1: $-2)) ** 2 - (X (3: $) - X (2: $-1))  **
2)… dC_dx = dC_
    dx. /dx3; dD_dx = dD_
    dx. /dx3; I = find (x=
    =0); [k1 k2] = size (I); yew (| (k1==0)
    ) then, X (I) = X (i+1)/10, end, //printf ("
1st order %s; 2nd order %s", G-string (min (dC_dx)), G-string (min (d2C_dx2)));
d2C_dx2 = D
    2C_dx2 + dC_dx. /x (2: $-1); end, Cf_ =
  Ci (2:
  $-1) +dt* (D (2: $-1). *d2C_dx2); yew (mode_ ==
  "whodunnit") then, Cf_ = Cf_ +
    dt* (dD_dx.*dC_dx); end, cf =
  zeros
  (1, N2  ); Cf (2: $-1) = Cf_; Cf (1) = CL (1); Cf ($) = CL (2); endfunction
, ////___
_
_______________________________________________________//Comparison
```

Annexe 2 Aster/Scilab A2.1 SECH_MENSI

/SECH_GRANGER /SECH_NAPPE A2.2 SECH_BAZANT





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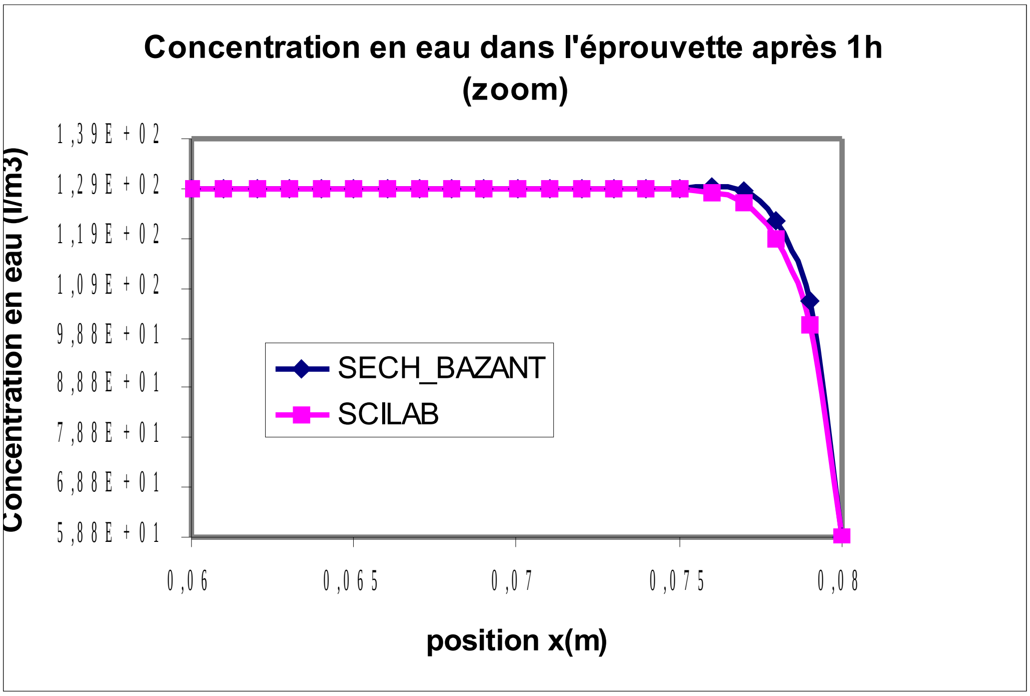

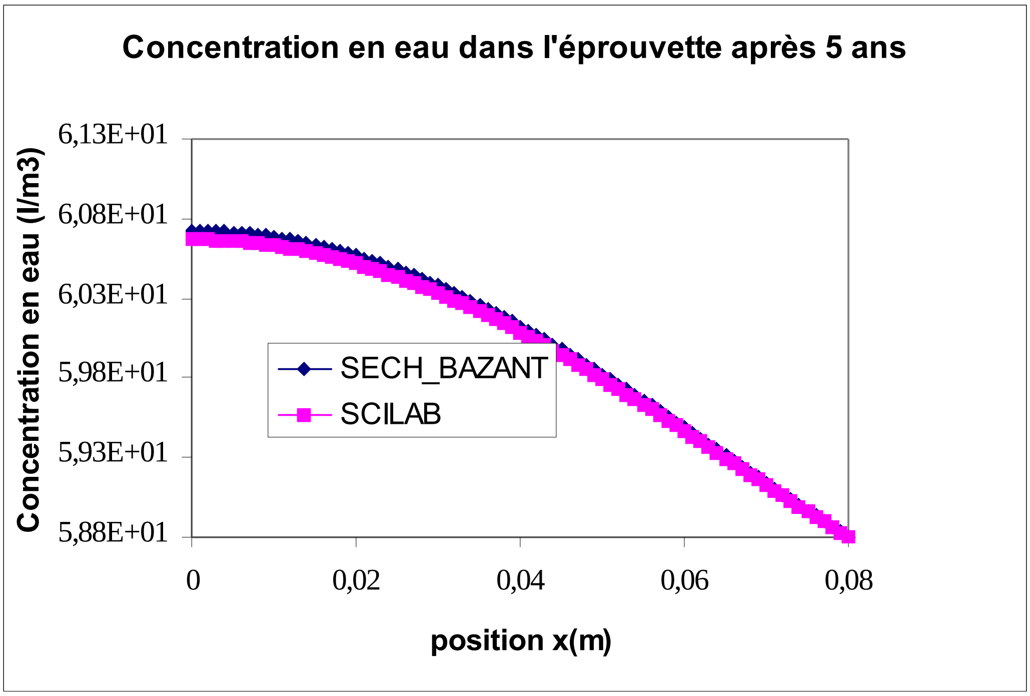

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