FORMED41 - Practical works of the formation “Génie Civil”: taking into account of the withdrawals in the study of a beam in inflection 3 points

Summary:

This test 3D allows to illustrate on a simple case the relative questions with the modeling of the withdrawals in the concrete; it highlights the effect of drying and the temperature on the distribution of the constraints.

It is about a concrete beam reinforced subjected to an inflection 3 points to which one adds a thermal request and of drying.

The objective of the test is to show the possibilities of modeling of the withdrawals by thermal chaining of calculations `THER_NON_LINE` and mechanics `MECA_STATIQUE`.

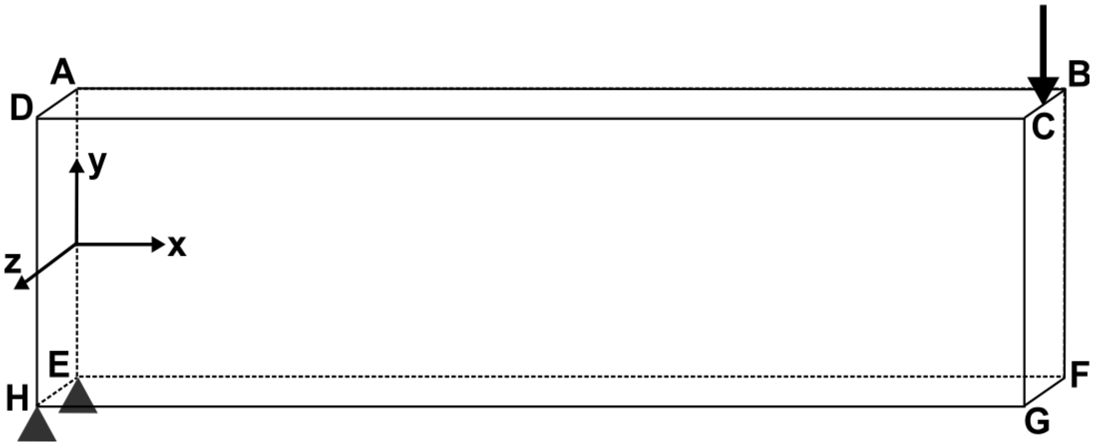
Modeling A corresponds to the calculation of the inflection in elasticity. It is used as comparison for other modelings.

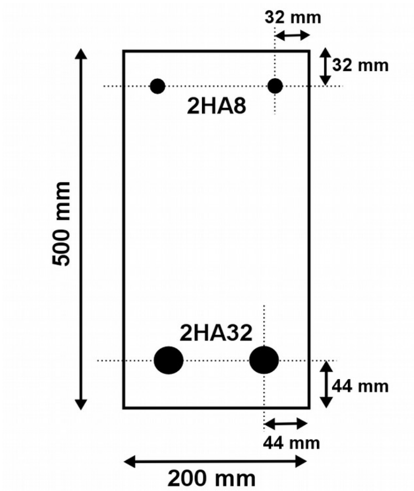
Modeling B corresponds to calculation with taking into account of the withdrawal of desiccation, the endogenous withdrawal and thermal dilation.

1 Problem of reference

1.1 Geometry

It is about a beam armed with $5m$ of length which one models only one quarter thanks to symmetries. Dimensions are given in millimetres.





1.2 Initial condition and thermal loadings

The initial temperature is uniform with $20°C$. The concrete is submitted to thermohydration.

The temperature is imposed on $20°C$ on the face $EFGH$.
The temperature is constant with $20°C$ up to 10 days then varies linearly $20°C$ with $40°C$ between 10 days and 30 days then is constant with $40°C$ on the face $ABCD$.

1.3 Initial condition and loadings of drying

The initial water concentration is uniform with $120 l/m^3$.

The water concentration is imposed on $50 l/m^3$ on the face $EFGH$.
The water concentration is imposed on $70 l/m^3$ on the face $ABCD$.

1.4 Boundary conditions and loadings mechanical

Conditions of symmetry
The plate is blocked according to Ox on the face $BCGF$ and following Oz on the face $ABFE$.

Limiting condition
The plate is blocked according to Oy on the side HE .

Loading

It is subjected to a force $\frac{F}{4}=3840\,N$ according to Oy distributed on the side BC what is equivalent to a total force of $F=15360\,N$ on the whole beam. The force is applied to the final moment of each calculation (in modeling A with the only step of time carried out and in modeling B to $t=100\ jours$).

1.5 Thermal properties of materials

Characteristics of the concrete are:

- Heat capacity $\rho C_p=2.4\mathrm{e}^6\,J/m^3/°C$;
- Conductivity $\lambda=1\,W/m/°C$;

and characteristics relating to the behavior hydrating following:

- heat per degree of hydration: $Q_0=1.14\mathrm{e}^8\,J/m^3$
- affinity function of the hydration (polynomial evaluation of the function known by points) and of the temperature (tablecloth):

$$A(h,T)=(50.12\mathrm{h}^6-190.76\mathrm{h}^5+258.38\mathrm{h}^4-123.71\mathrm{h}^3-11.82\mathrm{h}^2+15.37\mathrm{h}+2.43)\exp\left(\frac{-QSR_K}{(273.15+T)}\right)$$

- with constant of Arrhenius: $QSR_K=4000/°K$.

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

1.6 Properties of materials of drying

The law of diffusion is used SECH_GRANGER :

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

- $A=3.3\mathrm{e}-13\,m^2/s$;
- $B=0.05$;
- $QSR=4000$
- $T_0=293\,°K=20\,°C$

1.7 Mechanical properties of materials

The behavior is elastic.

Characteristics of steels are:

- Young modulus $E_a=200\,000\,MPa$;
- Poisson's ratio $\nu=0.3$;

Characteristics of the concrete are:

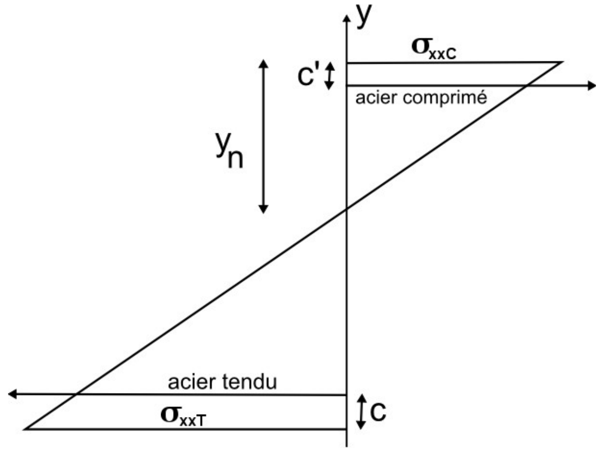
- Young modulus $E_b=32\,000\,MPa$ for modeling A. In modeling B, it varies linearly according to the temperature of $E_b=30\,000\,MPa$ for $T=0\,°C$ with $E_b=40\,000\,MPa$ for $T=100\,°C$;
- Poisson's ratio $\nu=0.2$;
- Thermal dilation $\alpha=1.2\mathrm{e}-6$ at the temperature of reference of $T_{ref}=20\,°C$
- Coefficient of withdrawal of desiccation $K_{des}=8\mathrm{e}\text{-}6$
- Endogenous coefficient of withdrawal $B_{endo}=9\mathrm{e}\text{-}5$

2 Reference solution

2.1 Elastic solution without withdrawal

One places oneself under the following assumptions:

- the sections of the beams remain plane
- there is perfect adherence between the concrete and steel
- the behavior is linear rubber band



One can thus evaluate the position of the neutral axis of the beam y_n according to the position of steels. For that, should be solved the following equation:

$$y_n\left(\frac{2n}{b}\left(A_s+A_S'\right)+2h\right)-\left(\frac{2n}{b}\left(A_S'c'+A_s\left(h-c\right)\right)+h^2\right)=0 \quad (1)$$

With:

A_s and A_s' : steel surfaces respectively tended and compressed in the section

c' and c' : concrete coating respectively below steels tended and to the top as of compressed steels

b and h : respectively the width and the height of the section of the beam

$n=\frac{E_a}{E_b}$: ratio enters the Young modulus of the concrete and steel

The longitudinal constraint of compression σ_{xxC} according to the bending moment and of the position of the neutral axis.

$$\sigma_{xxC}=\frac{Mf}{\left(A_s n\frac{\left(h-c-y_n\right)^2}{y_n}+A_s' n\frac{\left(y_n-c'\right)^2}{y_n}+\frac{by_n^2}{3}+b\frac{\left(h-y_n\right)^3}{y_n}\right)} \quad (2)$$

$$Mf(x)=\frac{Fx}{2} \quad (3)$$

The digital application gives:

$$y_n=0.2674 \quad (4)$$

And in $x=2.5\,m$ and $y=0{,}25\,m$, the maximum compressive stress is worth:

$$\sigma_{xxC}=-2.05\,MPa \quad (5)$$

By using the linearity of the constraints in the section, the maximum stress tensile in

$$\sigma_{xxT}=1.78\,MPa \quad (6)$$

2.2 Solution with withdrawals

One can easily evaluate the deformations due to the withdrawal of desiccation and thermal dilation where one knows the values of the water concentration and the temperature. For the endogenous withdrawal, one evaluates the degree of hydration starting from the interpolation used for the definition of the parameters of hydration. One a:

- in G with $t>30\mathrm{j}$:

$T=20\,°C$ thus $\varepsilon_{th}=\alpha(T-T_{ref})=0$
$C=50\,l/m^3$ thus $\varepsilon_{sec}=-K_{des}(C_0-C)=-5.6\mathrm{e}-4$
$h=0{,}95$ thus $\varepsilon_{endo}=-B_{endo}h=-8{,}55\mathrm{e}\text{-}5$

- in G with $t>30\mathrm{j}$:

$T=40\,°C$ thus $\varepsilon_{th}=\alpha(T-T_{ref})=2.4\mathrm{e}-5$
$C=70\,l/m^3$ thus $\varepsilon_{sec}=-K_{des}(C_0-C)=-4\mathrm{e}\text{-}4$
$h=0{,}95$ thus $\varepsilon_{endo}=-B_{endo}h=-8{,}55\mathrm{e}\text{-}5$

Constraints in G are not calculated analytically but result from a calculation on a very fine grid (32000 `HEXA20` and 155369 nodes).

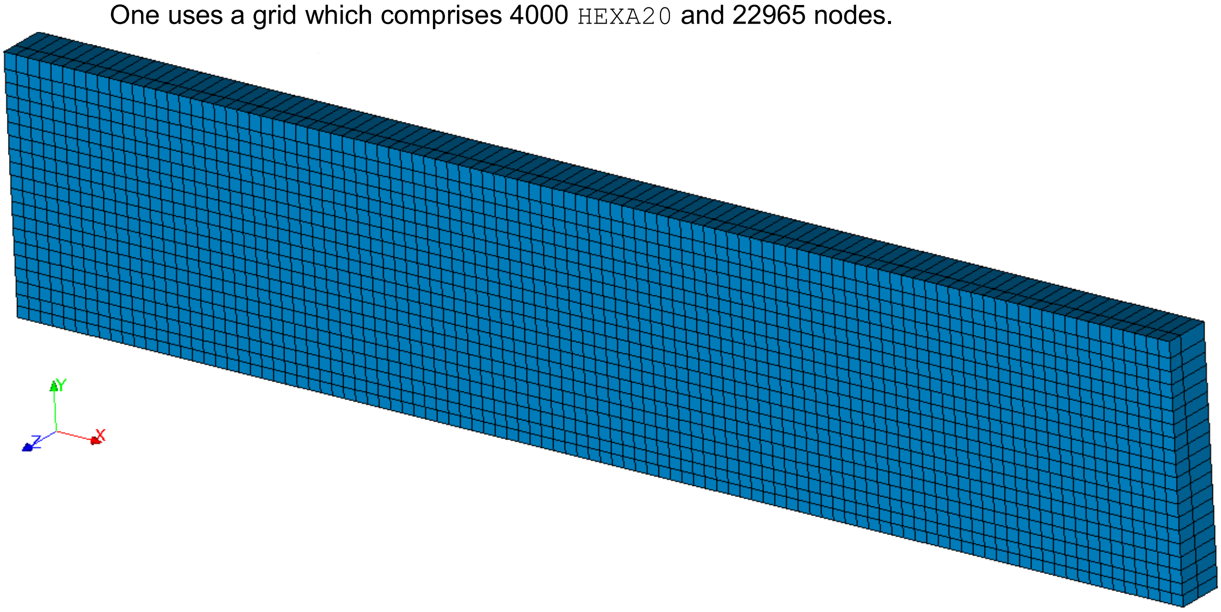
3 Modeling A

3.1 Characteristics of modeling

Elastic design on a voluminal model (3D). The loading is defined in the § 1.4.

3.2 Characteristics of the grid

One uses a grid which comprises 4000 HEXA20 and 22965 nodes.



3.3 Sizes tested and results

One tests the value of the longitudinal constraint:

Component	Type of reference	Value	Tolerance
SIGM_NOEU – $SIXX$ in G	ANALYTICAL	$1.78\,MPa$	2.00%
SIGM_NOEU – $SIXX$ in G	NON_REGRESSION	$1.75388\,MPa$	0.1%

4 Modeling B

4.1 Characteristics of modeling

Three successive calculations are done:

- Thermal calculation as described in 1.2 in modeling 3D_DIAG;
- Calculation of drying as described in 1.3 on the same model;
- Elastic design such as in modeling A.

4.2 Characteristics of the grid

One uses the same grid as the modeling A which comprises 4000 HEXA20 and 22965 nodes for the elastic design. For thermal calculations and of drying, one uses this same linear grid but. Steels are not taken into account for calculations thermics and of drying.

4.3 Sizes tested and results

One tests the value of the deformations of withdrawals of desiccation and dilation:

Component	Type of reference	Value	Tolerance
EPVC_ELNO – EPTHER_L in C	ANALYTICAL	2.4e-5	1%
EPVC_ELNO – EPTHER_L in C	NON_REGRESSION	2.4e-5	0.1%
EPVC_ELNO – EPSECH in C	ANALYTICAL	4th-4	1%
EPVC_ELNO – EPSECH in C	NON_REGRESSION	-4.e-4	0.1%
EPVC_ELNO – EPSECH in G	ANALYTICAL	-5.6e-4	1%
EPVC_ELNO – EPSECH in G	NON_REGRESSION	-5.6e-4	0.1%
EPVC_ELNO – EPHYDR in C	ANALYTICAL	-8.55e-5	4%
EPVC_ELNO – EPHYDR in C	NON_REGRESSION	-8.2825e-5	0.1%
EPVC_ELNO – EPHYDR in G	ANALYTICAL	-8.55 E 5	4%
EPVC_ELNO – EPHYDR in G	NON_REGRESSION	-8.2825e-5	0.1%

The value of the constraint is tested:

Component	Type of reference	Value	Tolerance
SIGM_NOEU – $SIXX$ in G	AUTRE_ASTER	1.7447e8	1%
SIGM_NOEU – $SIXX$ in G	NON_REGRESSION	1.727481e8	0.1%

5 Implementation of the TP

5.1 Unfolding of the TP

It is a question of concluding a calculation chaining thermohydration, drying and mechanics. This TP allows:

- to put in work a thermal calculation and of drying in Code_Aster: management of the loading, materials, the behavior and the parameters of THER_NON_LINE ;
- to understand and implement the concept of variable of order;
- to define parameters of a law of behavior which depend on variables of orders;
- with regard to the test, script Python generating the geometry and the grid in Salomé is in the file datg associated with the test.

5.2 Geometry and grid

The geometry and the grid are directly generated by while launching provided script.

5.3 Elastic design

The elastic design corresponding to modeling A is carried out,

To create a Code_Aster study in Salomé_Méca using the generated grid and the command file of modeling A.
To open the file .rmed result in Post-Pro or Paravis and to observe the state of stress of the beam

5.4 Addition of thermal calculation

The objective is to modify modeling A to reproduce modeling B, i.e. to add calculations thermics and of drying.

To record the command file of modeling A under another name and to open it in Eficas and to modify it as follows:
To create a new linear grid starting from the initial quadratic grid with CREA_MAILLAGE .
To create a model THERMICS using modeling 3D_DIAG.
To define the thermal parameters DEFI_MATERIAU and to assign material to the concrete meshs.
To define the thermal loading on the faces concerned in AFFE_CHAR_THER_F with TEMP_IMPO.
To define a list of moments from 0 to 100 days which passes by 10 days and 30 days.
To use THER_NON_LINE to solve the problem of thermics by using the relation THER_HYDR

5.5 Addition of the calculation of drying

To add the parameters of drying in DEFI_MATERIAU with SECH_GRANGER.
To define the loading of drying on the faces concerned in AFFE_CHAR_THER_F with TEMP_IMPO.
To use THER_NON_LINE to solve the problem of drying. Not to forget to indicate the result of

preceding thermics in EVOL_THER_SECH.

5.6 Taking into account of the withdrawals

To create a function of the temperature defining the Young modulus.
To modify the mechanical parameters in DEFI_MATERIAU with ELAS_FO. To add the withdrawal and dilation coefficient of desiccation.
To use PROJ_CHAM for to project the results of drying and thermics precedents, defines on the linear grid, the quadratic grid.
To add in AFFE_MATERIAU variables of order temperature, hydration and drying associated with the projected preceding results. Not to forget to specify the values of reference.
To add the list of moments and the function of loading to the order MECA_STATIQUE already presents. To remove the loading of inflection and to stop calculation a step before the end.
To add an order MECA_STATIQUE with the loading of inflection which calculation the last moment.
To add in CALC_CHAM the calculation of the option EPVC_ELNO who calculates the deformations due to the withdrawals.

5.7 Analysis of the results

One will be able to use the modulE VISU OU PARAVIS of Salomé to visualize the fields of displacements, constraints and of deformation.
One will be able for example to visualize the constraints along the segment BF and to observe stresses tensile high S in skin due to the withdrawal of desiccation.

6 Summary of the results

This test makes it possible to show how to carry out a calculation chained of thermics, drying and mechanics on reinforced concrete. One amongst other things observes the increase in the pressures in skin because of withdrawal of desiccation.