FORMA41 - Practical works of training “Civil engineer”: taking into account of the shrinkages in the study of a beam in bending 3 points

Summarized:

This test $3D$ makes it possible to illustrate on a simple case the relative questions with the modelization of the shrinkages in the concrete; it highlights the effect of drying and the temperature on the distribution of the stresses.

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

The purpose of the test is to show the possibilities of modelization of the shrinkages by thermal sequence of computations `THER_NON_LINE` and mechanical `MECA_STATIQUE`.

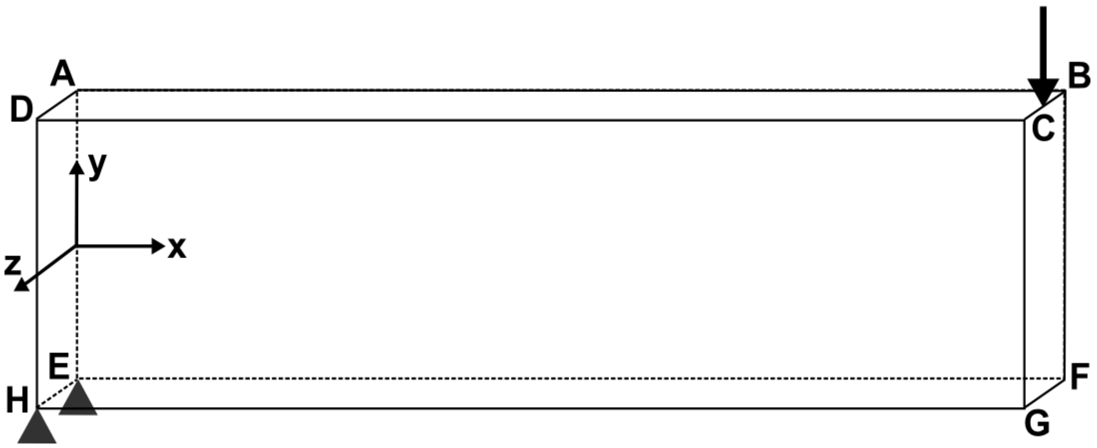
The modelization A corresponds to the computation of bending in elasticity. It is used as comparison for the other modelizations.

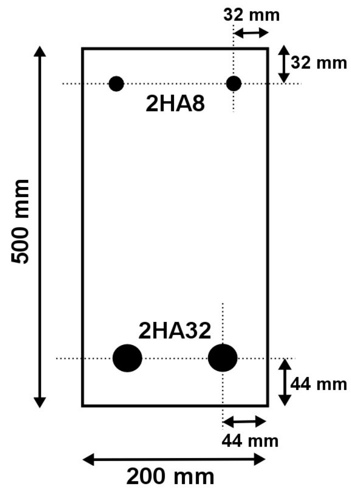
The modelization B corresponds to computation with taking into account of the shrinkage of desiccation, the endogenous shrinkage and thermal thermal expansion.

1 Problem of reference

1.1 Geometry

It acts D `a beam armed $5m$ length which one models only one quarter thanks to symmetries. Dimensions are given in millimetres.





1.2 Thermal initial condition and 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 Mechanical boundary conditions and loadings

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

Condition limits
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 final moment each computation (in modelization A with only time step carried out and in modelization B with $t=100\ jours$).

1.5 Thermal properties of the materials

the characteristics of the concrete are:
- Heat capacity $\rho C_p=2.4e^6 J/m^3/°C$;
- Conductivity $\lambda=1\,W/m/°C$;

and the characteristic relating to the behavior hydrating following:
- heat per degree of hydration: $Q_0=1.14e^8 J/m^3$
- affinity function of the hydration (polynomial evaluating of the function known by points) and of the temperature (three-dimensions function):

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

- 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 the materials of drying

One uses the model of diffusion `SECH_GRANGER` :

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

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

1.7 Mechanical properties of the materials

the behavior is elastic.

The characteristics of steels are:
- Young modulus $E_a=200\,000\,MPa$;
- Poisson's ratio $\nu=0.3$;

The characteristics of the concrete are:

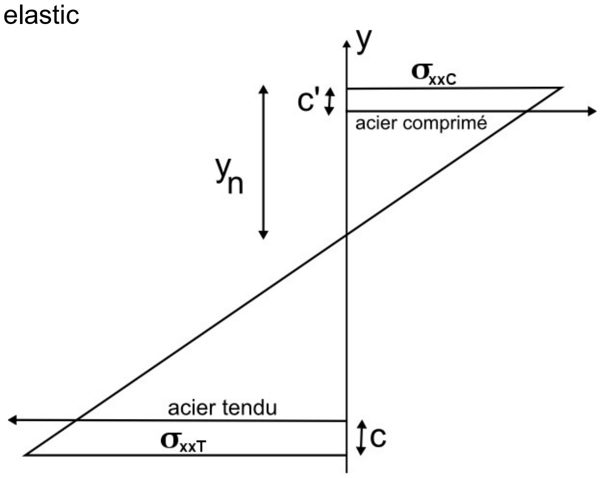
- Young modulus $E_b=30\,000\,MPa$ for modelization A. In modelization B, it varies linearly according to the temperature of $E_b=30\,000\,MPa$ for $T=0\,°C$ with $E_b=40\,000\,MPa$ for $T=100\,°C$;
- Poisson's ratio $\nu=0.2$;
- Thermal thermal expansion $\alpha=1.2\mathrm{e}-6$ with the reference temperature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

2 elastic Reference solution

2.1 Solution without shrinkage

One is placed under the following assumptions:

- the sections of the beams remain plane
- there is perfect dependancy between the concrete and steel
- the behavior is linear elastic



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:

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

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 beam:

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

the longitudinal stress 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 numerical 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 means of the linearity of the stresses in the section, the maximum stress tensile in

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

2.2 Solution with shrinkages

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

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

$T = 20\,°C$ thus $\varepsilon_{th} = \alpha(T - T_{ref}) = 0$

$C = 50\,l/m^3$ thus $\varepsilon_{sec} = -K_{des}(C_0 - C) = -5.6\text{e}-4$

$h = 0{,}95$ thus $\varepsilon_{endo} = -B_{endo}\,h = -8{,}55\text{e-}5$

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

$T = 40\,°C$ thus $\varepsilon_{th} = \alpha(T - T_{ref}) = 2.4\text{e}-5$

$C = 70\,l/m^3$ thus $\varepsilon_{sec} = -K_{des}(C_0 - C) = -4\text{e-}4$

$h = 0{,}95$ thus $\varepsilon_{endo} = -B_{endo}\,h = -8{,}55\text{e-}5$

the stresses in G are not calculated analytically but result from a computation on a very fine mesh (32000 `HEXA20` and 155369 nodes).

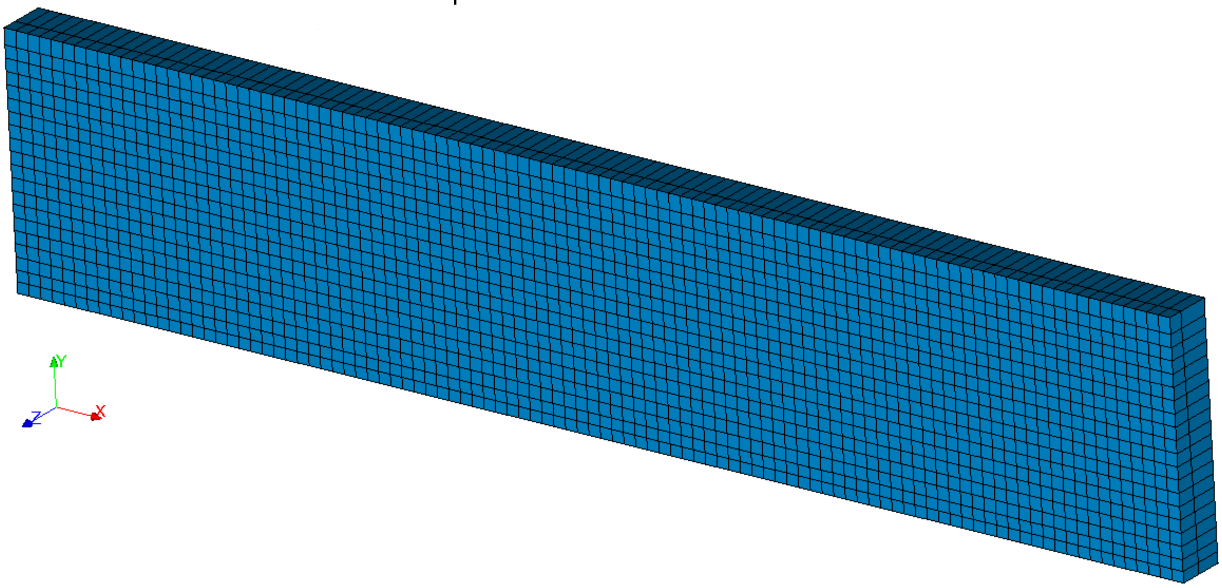
3 Modelization A

3.1 Characteristic of the modelization

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

3.2 Characteristics of the mesh

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



3.3 Quantities tested and results

One tests the value of the longitudinal stress:

Standard	component of reference	Value	Tolerance
SIGM_NOEU – $SIXX$ in G	ANALYTIQUE	$1.78\,MPa$	2,00%
SIGM_NOEU – $SIXX$ in G	NON_REGRESSION	$1.75388\,MPa$	0,1%

4 Modelization B

4.1 Characteristic of the modelization

One does three successive calculations:
- Thermal computation as described into 2 in modelization `3D_DIAG`;
- Computation of drying as described into 2 on the same model;
- Elastic design such as in modelization A.

4.2 Caractéristiques of the mesh

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

4.3 Quantities tested and results

One tests the value of the strains of shrinkages of desiccation and thermal expansion:

Standard	component of reference	Value	Tolerance
`EPVC_ELNO` – `EPTHER_L` in C	`ANALYTIQUE`	2.4e-5	1%
`EPVC_ELNO` – `EPTHER_L` in C	`NON_REGRESSION`	2.4e-5	0.1%
`EPVC_ELNO` – `EPSECH` in C	`ANALYTIQUE`	4th-4	1%
`EPVC_ELNO` – `EPSECH` in C	`NON_REGRESSION`	-4.e-4	0.1%
`EPVC_ELNO` – `EPSECH` in G	`ANALYTIQUE`	-5.6e-4	1%
`EPVC_ELNO` – `EPSECH` in G	`NON_REGRESSION`	-5.6e-4	0.1%
`EPVC_ELNO` – `EPHYDR` formulates C	`-8.55e-5`	4%	EPVC_ELNO
`of them` – `EPHYDR` formulates C	`NON_REGRESSION`	-8.2825e-5	0.1%
`EPVC_ELNO` – `EPHYDR` formulates G	`ANALYTIQUE`	-8.55 E 5	4%
`EPVC_ELNO` – `EPHYDR` formulates G	`-8.2825e-5`	0.1%	of them

One tests the value of the stress:

Standard	component 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 Déroulement of the TP

It acts to conclude a computation chaining thermohydration, drying and mechanics.
This TP allows:
- to put in work a thermal computation and of drying in Code_Aster: management of the loading, the materials, the behavior and the parameters of THER_NON_LINE ;
- to understand and implement the notion of command variable;
- to define parameters of a constitutive law which depend on command variables;
- with regard to the test, script Python generating the geometry and the mesh in Salomé is in the file datg associated with the test.

5.2 Geometry and mesh

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

5.3 Elastic design

The computation elastic corresponding to the modelization A is carried out,

To create a study Code_Aster in Salomé_Méca using the generated mesh and the command file of modelization A.
Ouvrir the results file .rmed in Post-Pro or Paravis and to observe the stress state of the beam

5.4 Addition of thermal computation

the purpose is to modify the modelization A to reproduce the modelization B, i.e. to add computations thermal and of drying.

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

5.5 Addition of computation drying

To add the parameters of drying in DEFI_MATERIAU with SECH_GRANGER.
To define the loading of drying on the sides 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 result thermal precedent in EVOL_THER_SECH.

5.6 Taking into account of the shrinkages

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 coefficient of thermal expansion and of shrinkage of desiccation.
To use PROJ_CHAM to project the results of drying and thermal precedents, defines on the linear mesh, the quadratic mesh.
To add in AFFE_MATERIAU the command variables temperature, hydration and drying associated with the projected preceding results. Not to forget to specify the values of reference.
To add the list of times and the function of loading to command MECA_STATIQUE already present. To remove the loading of bending and to stop computation a step before the end.
To add a command MECA_STATIQUE with the loading of bending which computation the last moment.
To add in CALC_CHAM the computation of the option EPVC_ELNO which calculates the strains due to the shrinkages.

5.7 Results One

analyzes will be able to use modulus VISU or PARAVIS of Salomé to visualize the fields of displacements, stresses and of strain.
One will be able for example to visualize the stresses along the segment BF and to observe stresses tensile high S in skin due to the shrinkage of desiccation.

6 Summary of the results

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