SSNP116 - Coupling creep/cracking - uniaxial Tension

Abstract:

This case of validation is intended to the model check coupling of the creep models of Granger with the models of plasticity/cracking. The coupling, initially restricted with some models of the nonlinear environment of *Code_Aster*, could be wide thereafter with more models. The parameters of the models of plasticity/cracking are selected in a particular way to model a nearly perfect elastoplastic behavior, and to be brought back to a problem presenting a relatively simple analytical solution.

The geometry consists of three linear elements (cubic and prisms in $3D$, squares and triangles in $2D$), and three quadratic elements, connected to the precedents by linear relations. The modelizations tested here are the modelizations `3D`, `C_PLAN`, and `D_PLAN`.

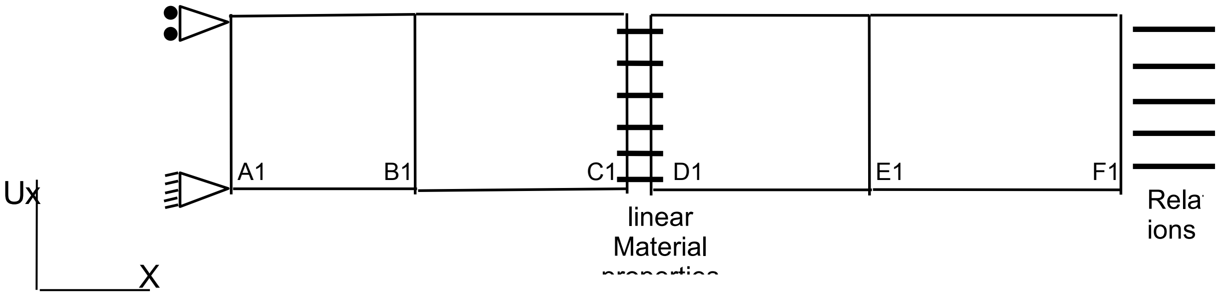
The loading is a uniaxial tension in imposed displacement.

One tests the coupling of the model of creep of Granger with `BETON_DOUBLE_DP and VMIS_ISOT_LINE`. One has the analytical solution in `3D` and `C_PLAN`, when there is not variation in the temperature and drying.

In 3D case and `D_PLAN`, one also tests the solutions obtained when there is variation in the temperature and the drying and activation of the corresponding shrinkages (with opposite effect). They are then tests of NON-regression.

1 Problem of reference

1.1 Geometry



1.2

the parameters of the constitutive laws are the following there:

For the mechanical characteristics in linear elasticity (`ELAS`):

Young modulus:	$E = 31\,000$ MPa
Poisson's ratio:	$\nu = 0.2$
Thermal coefficient of thermal expansion:	$\alpha = 10^{-5}$
Coefficient of shrinkage of desiccation:	$\kappa = 10^{-5}$

For the nonlinear mechanical characteristics of model `BETON_DOUBLE_DP` :

Strength in uniaxial pressing:	$f\,'c = 40\,N/mm^2$
Strength in uniaxial tension:	$f\,'t = 4\,N/mm^2$
Ratio of strength in biaxial compression/uniaxial pressing:	$\beta = 1.16$
Energy of fracture in compression:	$Gc = 10\,Nmm/mm^2$
Energy of fracture in tension:	$\mathrm{Gt} = 10000\,Nmm/mm^2$. *to simulate a hardening quasi no*
Ratio of the elastic limit to strength in uniaxial pressing:	$33.33\,\%$

For the mechanical characteristics of the model with linear hardening `VMIS_ISOT_LINE` :

Yield stress:	$Sy = 4\,N/mm^2$
Slope of hardening:	$\mathrm{D\_sigm\_epsi} = 0.1\,N/mm^2$

For the mechanical characteristics of the model of creep of `GRANGER` :

Coefficient J_1 *:*	$J_1 = 0.2\,MPa^{-1}$
Coefficient τ_1 *:*	$\tau_1 = 4\,320\,000\,s$

Coefficient Q/R *:* QsR_K = 0.K
The curve of desorption is worth 1 for all values of the hygroscopy, to simplify the analytical solution.

1.3 Mechanical boundary conditions and loadings

For computations in 3D :

- Face in $x=0$ first cube (its): blocked according to ox ,
- Nodes of the sides in $y=0$: blocked according to oy ,
- Nodes of the sides in $z=0$: blocked according to oz ,
- Relation linear (`LIAISON_DDL`) between the nodes end of the sides confused of the adjacent elements linear and quadratic (nodes $c1$ $c2$ $c3$, $c4$ bound with the nodes $d1$ $d2$ $d3$, $d4$),
- Relation linear (`LIAISON_UNIF`) on the face sd to bind displacements following ox of the quadratic nodes of this vis-a-vis those of the top nodes,
- Face in $x=x_{max}$ last cube (sf): Tension exerted according to ox .

For computations in 2D :

- Line in $x=0$ first square (it): blocked according to ox ,
- Nodes of the lines in $y=0$: blocked according to oy ,
- Relation linear (`LIAISON_DDL`) between the nodes end of the lines confused of the adjacent elements linear and quadratic (nodes $c1$, $c2$ bound with the nodes $d1$, $d2$),
- Relation linear (`LIAISON_UNIF`) on line ld binding displacements following x of the quadratic nodes of this line to those of the top nodes,
- Line in $x=x_{max}$ last square (lf): Tension exerted according to ox .

The field of temperature is either constant (the first computation), or crescent of $0°C$ with $20°C$ for all other computations. If the temperature varies, it is supposed that the field of drying varies from 1 to 0. The characteristics material are constant. Moreover, one applies a coefficient of non-zero shrinkage of desiccation, in such way that the shrinkage of desiccation compensates for thermal thermal expansion, to check that these 2 phenomena are well taken into account.

2 Reference solution

2.1 Method of calculating used for the reference solution

to be able to calculate a simple analytical solution, the following choices were carried out, the purpose being to validate the coupling and not the models of plasticity/cracking or creep:

- a creep model of Granger with only one model of Kelvin in series,
- a model of plasticity/cracking modelling a perfect elastoplastic model,
- a loading of uniaxial tension.

The reference solution is calculated in an analytical way, knowing that in tension, only the criterion of tension is activated. The equations of the model are brought back to scalar equations making it possible to calculate the analytical solution. The only difficulty comes from the determination of the beginning of the plasticity (urgent and strain of creep) which requires to solve by a numerical method a nonlinear equation with an unknown.

If the temperature is not constant, creep is more complex to solve, the analytical solution was not calculated. They are thus tests of NON-regression. However, in 3D case and `D_PLAN` , one can check that one gets the same results with the 2 models.

The imposed strain (displacement of an end of structure) is a linear function of time making it possible to bring into play creep and plasticity.

2.2 Computation of the reference solution

One notes ε , the component xx of the total deflection ε_e , the component xx of the elastic strain, ε_{fl} the component xx of the strain of creep of Granger, and ε_{pl} the component xx of the plastic strain, σ the component xx of the stress, and E it Young modulus.
The model of creep retained comprises that only one model of Kelvin in series and the model of plasticity/cracking is a nearly perfect model elastoplastic (slope of hardening quasi null), which makes it possible to easily calculate the analytical solution of the coupling creep/plasticity, in the case of a uniaxial simple tension. The nearly perfect elastoplastic model can be obtained starting from the models of *Code_Aster* `BETON_DOUBLE_DP` or `VMIS_ISOT_LINE` , by choosing the set of parameters which is appropriate (hardening quasi no one). The loading is a uniaxial tension in imposed displacement. One thus imposes a total deflection proportional to passed time, form $\varepsilon_{xx}=\lambda_0 . t$. As there is no force exerted in the other directions, the stress field is uniaxial. One can thus bring back oneself to a problem $1\mathrm{D}$ for the resolution, which makes it possible to calculate in the second time of the strains in the transverse directions with the loading (yy and zz).

$\sigma=(\sigma_{xx},0,0,0,0,0)$ and the $\varepsilon=(\varepsilon_{xx},\varepsilon_{yy},\varepsilon_{zz},0,0,0)$

equations of the model of creep and the model of plasticity merge with the following scalar equations, by omitting the index xx corresponding to the first component of the tensors:

$\varepsilon=\lambda_0 . t$ (imposed tension)

$$\varepsilon=\varepsilon_e+\varepsilon_{fl}+\varepsilon_{pl}$$

$\sigma=\mu\dot{\varepsilon}_{fl}+K\varepsilon_{fl}$ with $\mu=\frac{\tau_s}{J_s}$ and $K=\frac{1}{J_s}$

$$\sigma=E\varepsilon_e \quad \sigma=E[\varepsilon-\varepsilon_{pl}-\varepsilon_{fl}]$$

Resolution in linear elasticity
Before reaching the threshold of plasticity, the plastic strain is null, which leads to:

$\varepsilon=\lambda_0 . t$ (imposed tension)

$$\varepsilon_{pl}=0$$

$$\varepsilon=\varepsilon_e+\varepsilon_{fl}$$

$\sigma=\mu\dot{\varepsilon}_{fl}+K\varepsilon_{fl}$ with $\mu=\frac{\tau_s}{J_s}$ and $K=\frac{1}{J_s}$

$\sigma=E\varepsilon_e \quad \sigma=E\left[\varepsilon-\varepsilon_{fl}\right]$

One obtains the differential equation allowing to calculate the strain of creep:

$\sigma=E\left[\varepsilon-\varepsilon_{fl}\right]=\mu\dot{\varepsilon}_{fl}+K\varepsilon_{fl}$ with $\varepsilon=\lambda_0 . t$

the strain of creep thus expresses itself as the sum of a linear function of time and an exponential function, type:

$$\varepsilon_{fl}(t)=a.t+b+\alpha e^{-\beta . t}$$

who gives in the differential equation:

$$0=\mu . \dot{\varepsilon}_{fl}(t)+K.\varepsilon_{fl}(t)+E.\varepsilon_{fl}(t)-E.\lambda_0 . t$$

That is to say:

$$0=\left[(K+E)b+\mu . a\right]+\left[(K+E)a-E.\lambda_0\right]t+\left[(K+E)\alpha-\mu . \beta . \alpha\right]e^{-\beta . t}$$

from where:

$$a=\frac{E.\lambda_0}{K+E} \quad b=-\frac{\mu}{K+E}\frac{E.\lambda_0}{K+E} \quad \beta=\frac{K+E}{\mu}$$

At initial time, one starts from a strain of creep null, which leads to:

$$\alpha=\frac{m}{K+E}\frac{E.\lambda_0}{K+E}$$

One obtains finally the statement of the strain of creep according to time:

$$\varepsilon_{fl}^{xx}(t)=\varepsilon_{fl}(t)=\frac{\lambda_0 . E}{K+E}\left[t-\frac{\mu}{K+E}\left(1-e^{-\frac{K+E}{\mu}t}\right)\right]$$

The component xx of the elastic strain is worth: $\varepsilon_e=\varepsilon-\varepsilon_{fl}$. That is to say:

$$\varepsilon_e^{xx}(t)=\varepsilon_e(t)=\frac{\lambda_0 . K}{K+E}t+\frac{\lambda_0 . E.\mu}{(K+E)^2}\left(1-e^{-\frac{K+E}{\mu}t}\right)$$

the components yy and zz elastic strain and of creep are obtained by multiplication of the component xx by the Poisson's ratio.

The component xx of the stress is worth: $\sigma=E.\varepsilon_e=E\left(\varepsilon-\varepsilon_{fl}\right)$. That is to say:

$$\sigma_{xx}(t)=\sigma(t)=\frac{\lambda_0 . K.E}{K+E}t+\frac{\lambda_0 . E^2 . \mu}{(K+E)^2}\left(1-e^{-\frac{K+E}{\mu}t}\right)$$

Threshold of elasticity
the behavior remains elastic until one reaches the elastic limit. In the case of a uniaxial tension, the equivalent stress is equal to the non-zero component of the stress. Plasticity thus intervenes when $\sigma_{xx}(t)=\sigma_{eq}=f_t$ (strength in tension), that is to say:

$$\frac{\lambda_0 . K.E}{K+E}t+\frac{\lambda_0 . E^2 . \mu}{(K+E)^2}\left(1-e^{-\frac{K+E}{\mu}t}\right)=f_t$$

This equation, solved by a numerical method, allows to obtain the time of the beginning of plasticization t_{plas} and the strain of creep this time:

$$\varepsilon_{fl^{plas}}=\varepsilon_{fl}(t_{plas})=\frac{\lambda_0.E}{K+E}\left[t_{plas}-\frac{\mu}{K+E}\left(1-e^{-\frac{K+E}{\mu}t_{plas}}\right)\right]$$

formulate Resolution in
plasticity of plasticity was selected in order to obtain a simple analytical resolution. It is about a model of nearly perfect plasticity, obtained by taking a particular clearance of parameters for the model of behavior leading to a slope of hardening quasi null. Therefore, in plastic phase, the stress (component xx), equal to the equivalent stress is worth strength in tension. The equations of the model are then:

$\varepsilon=\lambda_0.t$ (imposed tension) and $\varepsilon=\varepsilon_e+\varepsilon_{fl}+\varepsilon_{pl}$

$\sigma=m\dot{\varepsilon}_{fl}+K\varepsilon_{fl}=\mu\dot{\varepsilon}_{fl}+K\left[\varepsilon-\varepsilon_e-\varepsilon_{pl}\right]$ with $\mu=\frac{\tau_s}{J_s}$ and $K=\frac{1}{J_s}$

$\sigma=E\varepsilon_e \quad \sigma=E\left[\varepsilon-\varepsilon_{pl}-\varepsilon_{fl}\right]=f_t$

with like initial conditions:

$t=t_{plas} \quad \varepsilon_{fl}(t_{plas})=\varepsilon_{fl^{plas}}$

what leads to the differential equation making it possible to calculate the strain of creep:

$\sigma=f_t=\mu\dot{\varepsilon}_{fl}+K\varepsilon_{fl}$

the strain of creep thus expresses itself in the form:

$\varepsilon_{fl}(t)=a+\alpha e^{-\beta.t}$

which gives in the differential equation:

$0=\mu.\dot{\varepsilon}_{fl}(t)+K.\varepsilon_{fl}(t)-f_t=\left[K.a-f_t\right]+\left[K.\alpha-\mu.\beta.\alpha\right]e^{-\beta.t}$ where:

$a=\frac{f_t}{K} \quad \beta=\frac{K}{\mu}$

At time t_{plas}, the strain of creep is worth $\varepsilon_{fl^{plas}}$, which leads to:

$\alpha=\left(\varepsilon_{fl^{plas}}-\frac{f_t}{K}\right)e^{\beta.t}$

One obtains finally the statement of the strain of creep according to time:

$\varepsilon_{fl^{xx}}(t)=\frac{f_t}{K}+\left(\varepsilon_{fl^{plas}}-\frac{f_t}{K}\right)e^{-\frac{K}{\mu}(t-t_{plas})} \qquad \varepsilon=\lambda_0.t$

the component xx of the elastic strain is worth: $\varepsilon_e=\frac{\sigma}{E}=\frac{f_t}{E}$

the component xx of the plastic strain is worth: $\varepsilon_{pl}=\varepsilon-\varepsilon_e-\varepsilon_{fl}=\lambda_0.t-\varepsilon_e-\varepsilon_{fl}$. That is to say:

$\varepsilon_{plas^{xx}}(t)=\lambda_0.t-\frac{f_t}{E}-\frac{f_t}{K}-\left(\varepsilon_{fl\,plas}-\frac{f_t}{K}\right)e^{-\frac{K}{m}(t-t_{plas})}$

the components yy and zz elastic strain and of creep are obtained by multiplication of the component xx by the Poisson's ratio.

The component xx of the stress is worth: $\sigma=f_t$

Numerical application:
One imposes a strain of 10^{-3} in 100 seconds, which gives $\lambda_0=10^{-5}$

the only difficulty consists in calculating the time of the plasticization t_{plas}, and the strain of creep $\varepsilon_{fl\,plas}$ which corresponds to him, per dichotomy for example. One obtains finally the parameters:

$$t_{plas} = 13.024296$$

$$e_{fl\,plas} = 1.20969985.10^{-6}$$

$$e = 1.2903226.10^{-4}$$

who allow to obtain the values of reference after plasticization of the concrete.

A 10 seconds, the behavior is a coupling creep/elasticity. A 100 seconds, the behavior is a coupling creep/plasticity:

times	10.100	
σ	3.0778607	4.0
ε	1.10-4	1.10-3
ε_{fl}	7.1417140.10-7	1.7316168.10-5
ε_{e}	9.9285829.10-5	1.2903226.10-4
ε_{fpl}	0.0	8.5365157.10-4

2.3 Uncertainty on the solution

It is negligible, about the machine accuracy.

2.4 Bibliographical references

The model was defined in the document of specification:

1) CS SI/311-1/420AL0/RAP/00.019 Version 1.1, “Development of coupling creep/cracking in *the Code_Aster* - Specifications”

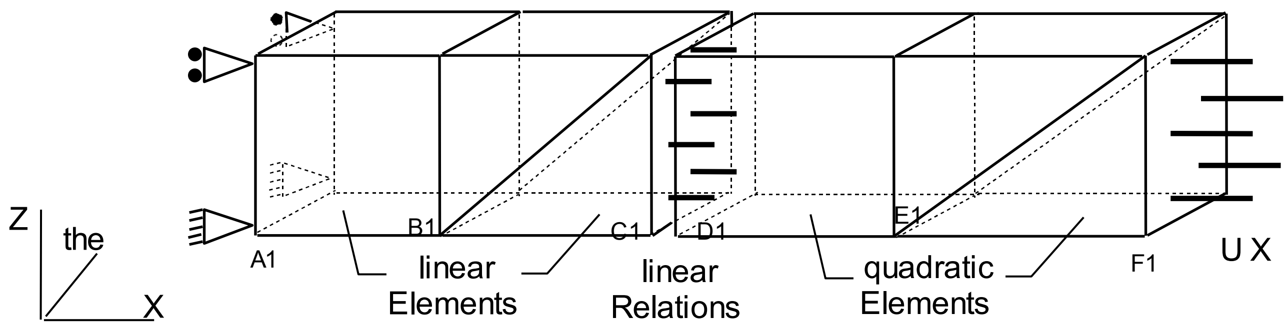
3 Modelization A

3.1 Characteristic of the modelization

3D (1 HEXA8, 2 **PENTA6**, 1 **HEXA20**, 2 **PENTA15)**

It acts of a cube with 8 nodes and two prisms with 6 nodes bound by linear relations to a cube to 20 nodes and of two prisms to 15 nodes. The group is subjected to a uniaxial tension according to the direction x. Dimensions according to y and z are unit. Dimensions according to the direction x are selected so that all the elements have the same characteristic length (this one is worth the cubic root of volume for the quadratic elements, and the cubic root of volume multiplied by $\sqrt{2}$ for the linear elements).

The stress fields and strains are uniform.
In $3D$, one validates the coupling of models BETON_DOUBLE_DP and VMIS_ISOT_LINE with model GRANGER_FP.



3.2 Characteristic of the mesh

Many nodes: 46
Number of meshes and type: 1 HEXA8, 2 PENTA6, 1 HEXA20, 2 PENTA15

3.3 Quantities tested and results

One tests the components xx of stress field SIGM_ELNO, the strain field of creep EPFP_ELNO, and plastic strain field EPSP_ELNO.
For the coupling with the BETON_DOUBLE_DP model , if the temperature and drying are constant and the solution analytical known, these values were tested at the point $C1$ located at the interface between the linear elements and the quadratic elements, and at the point $F1$ located at the end of structure, where is applied imposed displacement (in x_{max}).
When the temperature and drying vary, the analytical solution was not calculated: one thus tests the same components as previously but only at the point $F1$ located at the end of structure. The solution obtained with BETON_DOUBLE_DP is tested as a NON-regression, but the values obtained are used then as reference for the model VMIS_ISOT_LINE .

The tests are carried out at time 10, when plasticity did not start, only creep is present, and at time 100, after the beginning of the plasticization of the concrete.

3.3.1 Computation with the BETON_DOUBLE_DP model in isotherm (Reference)

Coupling GRANGER_FP/BETON_DOUBLE_DP

- **at the point** $C1$

Identification	Reference	*Aster*	% difference
σ_{xx} for $\varepsilon_{xx}\,10^{-4}$	3.07786	3.07787	1.9.10 $^{-4}$
ε_{xx}^{fl} for $\varepsilon_{xx}\,10^{-4}$	7.14171 10 $^{-7}$	7.140035 10 $^{-7}$	-0.023
σ_{xx} for $\varepsilon_{xx}\,10^{-3}$	4.0	3.999999	-2.0.10 $^{-5}$
ε_{xx}^{fl} for $\varepsilon_{xx}\,10^{-3}$	1.73162 10 $^{-5}$	1.731596 10 $^{-5}$	-0.001
ε_{xx}^{p} for $\varepsilon_{xx}\,10^{-3}$	8.53652 10 $^{-4}$	8.536546 10 $^{-4.3.1}$	10 $^{-4}$

- **at the point** $F1$

Identification	Reference	*Aster*	% difference
σ_{xx} for $\varepsilon_{xx}\,10^{-4}$	3.07786	3.07787	1.9.10 $^{-4}$
ε_{xx}^{fl} for $\varepsilon_{xx}\,10^{-4}$	7.14171 10 $^{-7}$	7.140035 10 $^{-7}$	-0.023
σ_{xx} for $\varepsilon_{xx}\,10^{-3}$	4.0	3.999998	-6.0.10 $^{-5}$
ε_{xx}^{fl} for $\varepsilon_{xx}\,10^{-3}$	1.73162 10 $^{-5}$	1.731596 10 $^{-5}$	-0.001
ε_{xx}^{p} for $\varepsilon_{xx}\,10^{-3}$	8.53652 10 $^{-4}$	8.536023 10 $^{-4}$	-0.006

3.3.2 Computation with the BETON_DOUBLE_DP model in nonisotherm (Non regression)

- **at the point** $F1$

Identification	*Aster*
σ_{xx} for $\varepsilon_{xx}\,10^{-4}$	3.077193
ε_{xx}^{fl} for $\varepsilon_{xx}\,10^{-4}$	7.357178 10 $^{-7}$
σ_{xx} for $\varepsilon_{xx}\,10^{-3}$	3.999998
ε_{xx}^{fl} for $\varepsilon_{xx}\,10^{-3}$	2.140534 10 $^{-5}$
ε_{xx}^{p} for $\varepsilon_{xx}\,10^{-3}$	8.495132 10 $^{-4}$

3.4 Computation with model `VMIS_ISOT_LINE` in nonisotherm

- **at the point** $F1$

Identification	*Aster*
σ_{xx} for $\varepsilon_{xx}\,10^{-4}$	3.077193
ε_{xx}^{fl} for $\varepsilon_{xx}\,10^{-4}$	7.357178 10 $^{-7}$
σ_{xx} for $\varepsilon_{xx}\,10^{-3}$	4.000009
ε_{xx}^{fl} for $\varepsilon_{xx}\,10^{-3}$	2.140537 10 $^{-5}$
ε_{xx}^{p} for $\varepsilon_{xx}\,10^{-3}$	8.495621 10 $^{-4}$

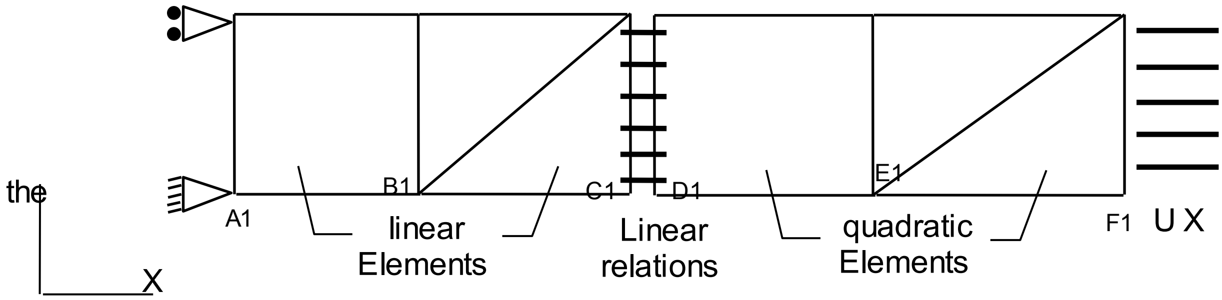
4 Modelization B

4.1 Characteristic of modelization

D_PLAN (1 QUAD4, 2 TRI3, 1 Q UAD8, 2 TRI6)

It acts of a square with 4 nodes and two triangles with 3 nodes bound by linear relations to a square to 8 nodes and of two triangles with 6 nodes. The group is subjected to a uniaxial tension according to the direction x. Dimensions according to y are unit. Dimensions according to the direction x are selected so that all the elements have the same characteristic length (root of surface for the quadratic elements, and root of the surface multiplied by $\sqrt{2}$ for the linear elements).

The stress fields and strains are uniform.
In $2D$ plane strains (D_PLAN), one tests the coupling between the BETON_DOUBLE_DP model with model GRANGER_FP. One tests also the coupling of model VMIS_ISOT_LINE with model GRANGER_FP. The analytical solution was not calculated in D_PLAN.



4.2 Characteristics of the mesh

Many nodes: 20
Number of meshes and type: 1 QUAD4, 2 TRI3, 1 QUAD8, 2 TRI6

4.3 Functionalities tested

One tests the components xx of stress field SIGM_ELNO and the strain field of creep EPFP_ELNO, and plastic strain field EPSP_ELNO at the point $F1$ located at the end of structure, where is applied imposed displacement (in x_{max}).

The analytical solution was not calculated in plane strain. One thus carries out only same computation with the 2 models of cracking to temperature and variable drying. The tests are of standard NON-regression.

The tests are carried out at time 10, when plasticity did not start, only creep is present, and at time 100, after the beginning of the plasticization of the concrete.

4.3.1 Computation with the BETON_DOUBLE_DP model in nonisotherm (Non regression)

At the point $C1$

Identification	Aster
σ_{xx} for $\varepsilon_{xx} 10^{-4}$	3.205409
ε_{xx}^{fl} for $\varepsilon_{xx} 10^{-4}$	7.357178 10 $^{-7}$
σ_{xx} for $\varepsilon_{xx} 10^{-3}$	4.382555
ε_{xx}^{fl} for $\varepsilon_{xx} 10^{-3}$	2.307822 10 $^{-5}$
ε_{xx}^{p} for $\varepsilon_{xx} 10^{-3}$	8.217046 10 $^{-4}$

At the point $F1$

Identification	Aster
σ_{xx} for $\varepsilon_{xx} 10^{-4}$	3.205409
ε_{xx}^{fl} for $\varepsilon_{xx} 10^{-4}$	7.357178 10 $^{-7}$
σ_{xx} for $\varepsilon_{xx} 10^{-3}$	4.382555
ε_{xx}^{fl} for $\varepsilon_{xx} 10^{-3}$	2.307822 10 $^{-5}$
ε_{xx}^{p} for $\varepsilon_{xx} 10^{-3}$	8.217039 10 $^{-4}$

4.3.2 Computation with model `VMIS_ISOT_LINE` in nonisotherm (Non regression)

At the point $F1$

Identification	Aster
σ_{xx} for $\varepsilon_{xx} 10^{-4}$	3.205409
ε_{xx}^{fl} for $\varepsilon_{xx} 10^{-4}$	7.357178 10 $^{-7}$
σ_{xx} for $\varepsilon_{xx} 10^{-3}$	4.614209
ε_{xx}^{fl} for $\varepsilon_{xx} 10^{-3}$	2.195353 10 $^{-5}$
ε_{xx}^{p} for $\varepsilon_{xx} 10^{-3}$	8.429335 10 $^{-4}$

5 Summary of the results

If one knows the analytical solution (NON-variation of temperature and of drying), this case test offers very satisfactory results with a lower deviation than 0.02% for all the calculation cases. The nombre of iterations for the plastic phase is generally about ten; This is explained by the choice of the model of nearly perfect plasticity, obtained with the model VMIS_ISOT_LINE, particular clearances of parameters. In fact, this same model used **without** coupling creep/cracking, under the same conditions of loading and with the same parameters, presents the same difficulties of convergence.

It is checked that under the effect of the increase in the temperature the strains of creep are increased ($+3\ \%$ approximately in the elastic phase, $+23\%$ in the plastic phase).

Lastly, in 3D and C_PLAN, one checks that the 2 models which were degenerated give many quasi-similar results. On the other hand, in D_PLAN, the model BETON_DOUBLE_DP is not equivalent to model VMIS_ISOT_LINE because of writing of the criterion which depends on the trace of the tensor of the strains and is thus not equivalent to the perfectly plastic model.