COMP003 – Test of behaviors specific to the concretes. Simulation in a material point

Summary:

This test implements a simulation of a way of loading in constraints or deformations in a material point, i.e. on a model such as the stress and strain states are homogeneous at any moment. It thus makes it possible to test a certain number of models of behavior specific to the concretes, with an aim of checking the robustness of their digital integration, their insensitivity compared to a change of units, the good taking into account of the variables of order whose the coefficients depend on the model, invariance compared to a total rotation applied to the problem.

Modeling a: this modeling makes it possible to validate the model BETON_RAG in $3D$.
Modeling b: this modeling makes it possible to validate the model BETON_UMLV_FP in $3D$.
Modeling C: this modeling makes it possible to validate the model BETON_BURGER_FP in $3D$.

1 Problem of reference

1.1 Geometry

Geometry generated automatically in the macro-order `SIMU_POINT_MAT` [U4.51.12] is single and simple: it is about a tetrahedron on side 1, with the nodes of which one applies linear relations to obtain a homogeneous stress and strain state.

1.2 Properties of material

The characteristics of materials are defined via the order `DEFI_MATERIAU`. The elastic characteristics are:

- $E = 32\,000\,MPa$,
- $\nu = 0.2$,

The other parameters describing the laws were selected starting from the CAS-tests of Code_Aster. The following table summarizes the whole of the laws of Code_Aster considered and the parameters associated:

Modeling	laws of behavior of *Code_Aster*	parameters selected	test retained for the choice of the parameters

With	`BETON_RAG`	`K_RS = 200000.`
		`K_IS = 20000.`
		`ETA_RS = 350000.`
		`ETA_IS = 2500000.`
		`K_RD = 100000.`
		`K_ID = 90000.`
		`ETA_RD = 2000000.`
		`ETA_ID = 3000000.`
		`EPS_0 = 0.0035`
		`TAU_0 = 5.`
		`F_C = 15.`
		`F_T = 8.0`
		`EPS_COMP = 6.0e-3`
		`EPS_TRAC = 5.0e-4`
		`LC_COMP = 1.0`
		`LC_TRAC = 1.0`
		`HYD_PRES = 0.0`
		`A_VAN_GE = 0.0`
		`B_VAN_GE = 1.9`
		`BIOT_EAU = 0.0`
		`MODU_EAU = 0.0`
		`W_EAU_0 = 1.0`
		`BIOT_GEL = 0.0`
		`MODU_GEL = 0.0`
		`VOL_GEL = 0.0`
		`AVANC_LI = 0.0`
		`SEUIL_SR = 0.0`
		`PARA_CIN = 0.0`
		`ENR_AC_G = 0.0`
			Nonrealistic values, for the needs for the test of data-processing checking.

B	`BETON_UMLV_FP`	`K_RS = 2.0E5 (MPa)`
		`ETA_RS = 4.0E10 (MPa/s)`
		`K_IS = 5.0E4 (MPa)`
		`ETA_IS = 1.0E11 (MPa/s)`
		`K_RD = 5.0E4 (MPa)`
		`ETA_RD = 1.0E10 (MPa/s)`
		`ETA_ID = 1.0E11 (MPa/s)`
			Parameters identical to test SSNV163A

Modeling	laws of behavior of *Code_Aster*	parameters selected	test retained for the choice of the parameters
C	BETON_BURGER_FP	K_RS = 2.0E5 (MPa) ETA_RS = 4.0E10 (MPa/s) ETA_IS = 1.0E11 (MPa/s) K_RD = 5.0E4 (MPa) ETA_RD = 1.0E10 (MPa/s) ETA_ID = 1.0E11 (MPa/s) KAPPA = 3.0E-3	Parameters identical to test SSNV163D

1.3 Boundary conditions and loadings

1.3.1 Characteristics of the way of loading

The loading suggested varies in a way uncoupled each component from the tensor of the deformations by successive stages. One proposes a cyclic way of load-discharge by covering the states of traction and compression as well as an inversion of the signs of shearings in order to test a broad range of values.

Schematically, it follows a course on 8 segments $[O-A-B-C-O-C'-B'-A'-O]$ where the second part of the way $[O-C'-B'-A'-O]$ is symmetrical compared to the origin of the first $[O-A-B-C-O]$.

1.3.2 Application of the requests

One under investigation brings back material point (by using the macro-order SIMU_POINT_MAT [U4.51.12]) by requesting a homogeneous element of manner while imposing in $3\mathrm{D}$, 6 components of the tensor of deformation:

$$\bar{\varepsilon}=\begin{bmatrix}\varepsilon_{xx} & \varepsilon_{xy} & \varepsilon_{xz}\\ \varepsilon_{xy} & \varepsilon_{yy} & \varepsilon_{yz}\\ \varepsilon_{xz} & \varepsilon_{yz} & \varepsilon_{zz}\end{bmatrix}$$

For a more general writing, the tensor of the deformations imposed will be broken up into a hydrostatic and deviatoric part on bases of shearing:

$$\bar{\varepsilon}=\begin{bmatrix}\varepsilon_{xx} & \varepsilon_{xy} & \varepsilon_{xz}\\ \varepsilon_{xy} & \varepsilon_{yy} & \varepsilon_{yz}\\ \varepsilon_{xz} & \varepsilon_{yz} & \varepsilon_{zz}\end{bmatrix}=p\begin{bmatrix}1&0&0\\0&1&0\\0&0&1\end{bmatrix}+d_1\begin{bmatrix}1&0&0\\0&-1&0\\0&0&1\end{bmatrix}+d_2\begin{bmatrix}0&0&0\\0&1&0\\0&0&-1\end{bmatrix}+\begin{bmatrix}0 & \varepsilon_{xy} & \varepsilon_{xz}\\ \varepsilon_{xy} & 0 & \varepsilon_{yz}\\ \varepsilon_{xz} & \varepsilon_{yz} & 0\end{bmatrix} \text{ in } 3\mathrm{D}$$

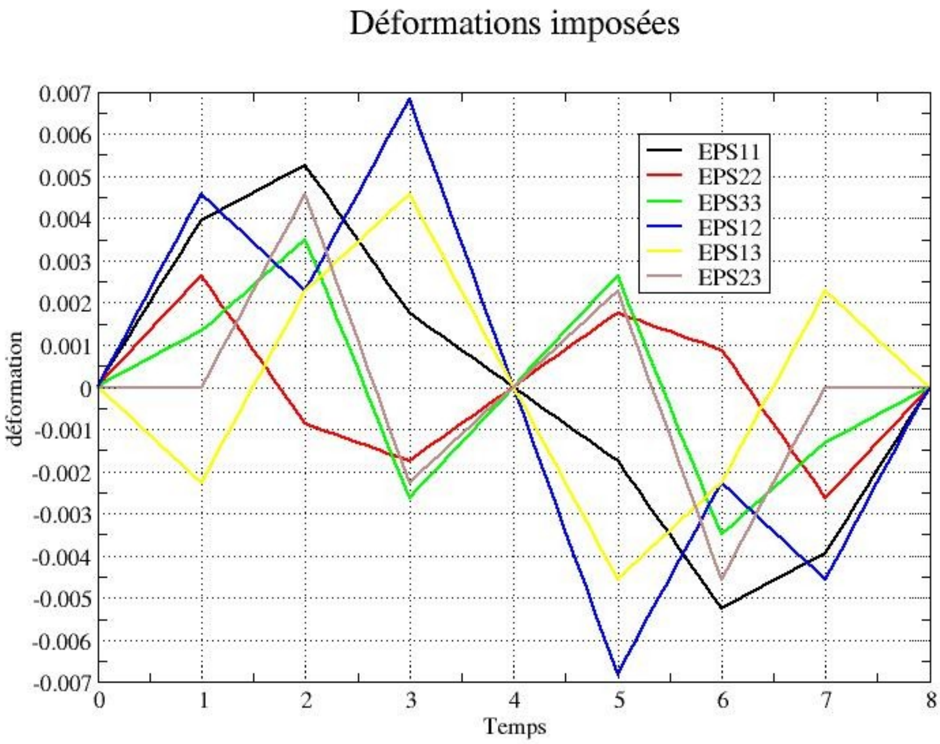
1.3.3 Description of the way of imposed deformation

The way applied is described in the table below, the values of deformations applied are gauged with respect to the elastic module:

N° segment	1	2	3	4	5	6	7	8
Segment	$O-A$	$A-B$	$B-C$	O	C'	B'	A'	O
$\varepsilon_{xx}\times E$	787.5	1050	350	0	-350	-1050	-787.5	0
$\varepsilon_{yy}\times E$	525.0	-175	-350	0	350	175	525	0
$\varepsilon_{zz}\times E$	262.5	700	-525	0	525	-700	-262.5	0

N° segment	1	2	3	4	5	6	7	8
$\varepsilon_{xy} \times E/(1+\nu)$	700	350	1050	0	-1050	-350	-700	0
$\varepsilon_{xz} \times E/(1+\nu)$	-350	350	700	0	-700	-350	700	0
$\varepsilon_{yz} \times E/(1+\nu)$	0	700	-350	0	350	-700	0	0
P	525	525	-175	0	175	-525	-525	0
$d1$	262.5	525	525	0	-525	-525	-262.5	0
$d2$	262.5	-175	350	0	-350	175	-262.5	0

This way is illustrated by the following graph:



1.4 Initial conditions

Worthless constraints and deformations.

2 Reference solution

This test proceeds, for each modeling, with an intercomparison between the reference solution (obtained with a step of fine time), the solution with a fairly coarse discretization, the solution with effect of the temperature (or another variable of order), the solution by changing the system of units (Pa in MPa), and that obtained after rotation.

2.1 Definition of the CAS-tests of robustness

One proposes 2 angles of analysis to test the robustness of the integration of the laws of behavior:
- studies of equivalent problems
- study of the discretization of the step of time

For each one of them, one studies the evolution of the relative differences between several calculations using the same law but presenting parameters or different options of calculations. The exploitation relates to the invariants of the tensor of the constraints: trace of the tensor, constraint of Von-Put and the internal variables of scalar nature.

The total convergence criteria are the values envisaged by default by Code_Aster. (`RESI_GLOB_RELA=10-6, ITER_GLOB_MAXI=10`). One adopted a usual diagram of Newton for the reactualization of the tangent matrix:
- calculation of the tangent matrix of prediction to each converged increment (`REAC_INC=1`)
- calculation of the coherent tangent matrix to each iteration of Newton `(REAC_ITER=1).`

2.2 Studies of equivalent problems

For a coarse discretization of the ways: 1 pas de time for each segment of the way, the solution obtained for each law is compared with 2 strictly equivalent problems for the state of the material point:
- Tpa , even way with a change of unit, one substitutes them Pa with MPa in the data materials and the possible parameters of the law,
- $Trot$, way by imposing the same tensor $\bar{\varepsilon}$ after a rotation: ${}^{t}R\cdot\bar{\varepsilon}\cdot R$ where R is a matrix of rotation, corresponding to a rotation of 30 degrees around the axis Oz .

For each one of these problems, the solution (invariants of the constraints, variable interns scalar) must be identical to the basic solution, obtained with the same discretization in time. The value of reference of the variation is thus 0. That means in practice that the found variation must be about the precision machine is approximately $1.E-15$.

2.3 Study of the discretization of the step of time

One studies the behavior of the integration of the laws according to the discretization. For the same modeling, therefore a given behavior, one studies two different discretizations in time here, while multiplying by 5 the number of steps of the way of loading. This led to the following discretization:

Calculation	T_1	$T_{réf}$ **reference solution**
Many intervals per segment of loading	5	25
Number of total step on the whole of the way	40	200

The reference solution, $T_{réf}$, is that obtained for $N=25$, that is to say 200 pas for the totality of the way. These solutions make it possible to judge sensitivity to the great steps of time and robustness of integration.

One defers to the §3.3 maximum differences between the two solutions for the whole of the way of loading.

3 Modeling A

3.1 Characteristics of modeling

The behavior tested is BETON_RAG , in 3D.

3.2 Sizes tested and results

Variations max	T_{Pa}	T_{rot}	T_1	$T_{réf}$
$V21$	7.6e-14	4.7e-08	5.7e-11	0
$VMIS$	1.3e-12	1.8e-05	2.21e-03	0
$TRACE$	2.0e-12	8.2e-06	1.56e-03	0

4 Modeling B

4.1 Characteristics of modeling

The behavior tested is BETON_UMLV_FP , in 3D.

4.2 Sizes tested and results

Variations max	T_{Pa}	T_{rot}	T_1	$T_{réf}$
$VMIS$	6.15e-15	2.68e-15	4.25e-04	0
$TRACE$	0.0	0.0	0.0	0

Note: One does not test internal variables, because they are the tensorial representation of the deformations of creep, therefore the values are related to the selected reference mark of coordinates.

5 Modeling C

5.1 Characteristics of modeling

The behavior tested is BETON_BURGER_FP, in 3D.

5.2 Sizes tested and results

Variations max	T_{Pa}	T_{rot}	T_1	$T_{réf}$
$V1$	0	0	0	0
$VMIS$	1.42e-14	1.58e-15	2.88e-9	0
$TRACE$	0	0	0	0

Note: One does not test internal variables, because they are the tensorial representation of the deformations of creep, therefore the values are related to the selected reference mark of coordinates.

6 Synthesis

For the behavior BETON_RAG, the results are satisfactory:

- the results are valid during a physical change of unit of the problem (Pa in Mpa)
- following a rotation, the results are correct but could undoubtedly be still improved
- results convergent with the step of time, and the diagrams of integration make it possible to use great steps of time.

For the behavior BETON_UMLV_FP, the results are very satisfactory:

- the results are valid during a physical change of unit of the problem (Pa in Mpa)
- following a rotation, the results are identical
- results convergent with the step of time, and the diagrams of integration make it possible to use great steps of time.

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