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

material point:

This test implements a simulation of a way of loading in stresses or strains in a material point, i.e. on a model such as the stress states and of strains 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 numerical integration, their insensitivity compared to a change of units, the good taking into account of the command variables whose the coefficients depend on the model, invariance compared to a total rotation applied to the problem.

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

1 Problem of reference

1.1 Geometry

the geometry generated automatically in macro-command 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 stress state and of homogeneous strain.

1.2 Properties of the material

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

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

the other parameters describing the models were selected starting from the benchmarks of Code_Aster. The following table summarizes all the models of Code_Aster considered and the associated parameters:

Modelization	constitutive laws of *Code_Aster*	parameters selected	test retained for the choice of parameters
A	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 data-processing test of 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

Modelization	constitutive laws of *Code_Aster*	parameters selected	test retained for the choice of 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 the test SSNV163D

1.3 Boundary conditions and loadings

1.3.1 Characteristic of the way of loading

the loading suggested varies in a way decoupled each component of the tensor of the strains by successive stages. One proposes a cyclic way of load-discharge by covering the states of tension and compression as well as an inversion of the signs of the shears in order to test a broad range of values.

Schematically, it follows a path 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 symmetric 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 means of macro-command `SIMU_POINT_MAT [U4.51.12])` by requesting a homogeneous element of way while imposing in $3D$, the 6 components of the strain tensor:

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

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

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

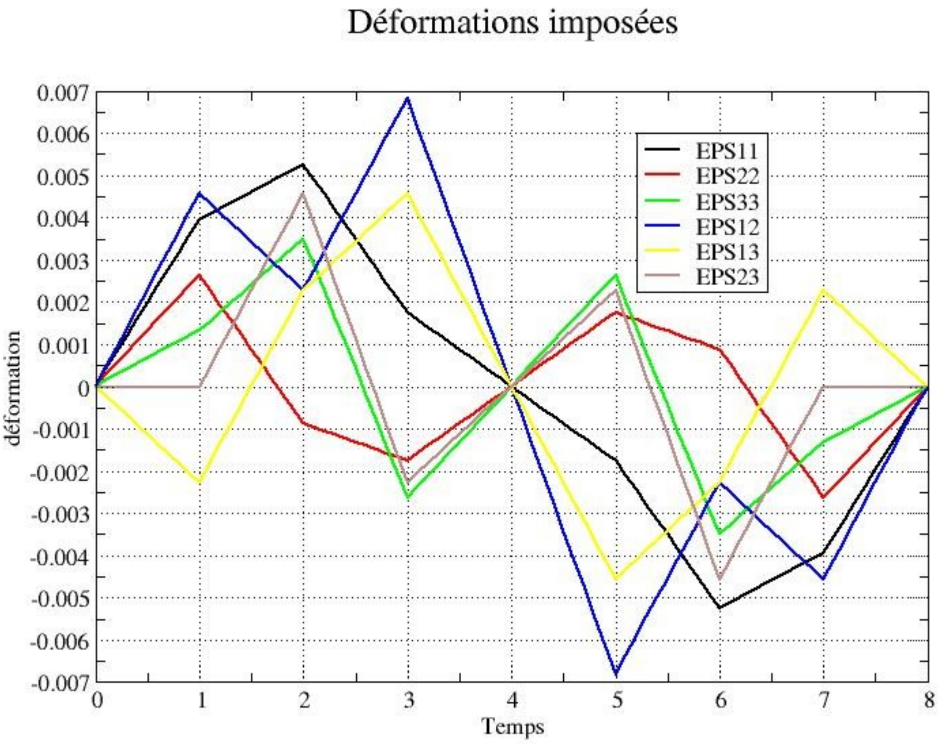
1.3.3 Description of the way of imposed strain

the way applied is described in the table below, the values of strains applied are gauged with respect to the elastic modulus:

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	0.3 50. 17 5			525	0

N° segment	1	2	3	4	5	6	7	8
$\varepsilon_{zz} \times E$	262.5	700	-525	0.525		-700	-262.5	0.700.350
$\varepsilon_{xy} \times E/(1+\nu)$			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	0.525.525
P			-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 Forced

initial conditions and null strains.

2 Reference solution

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

2.1 Definition of the benchmarks of robustness

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

For each one of them, one studies the evolution of the relative differences between several computations using the same model but presenting parameters or different computation options. The operating relates to the invariants of the tensor of the stresses: trace tensor, stress of Von-Put and the local 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:
- computation of the tangent matrix of prediction to each converged increment (`REAC_INC=1`)
- computation 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 time step for each segment of the way, the solution obtained for each model is compared with 2 strictly equivalent problems for the state of the material point:
- Tpa , even way with a change of unit, one substitutes to them Pa for MPa in the data materials and the possible parameters of the model
- $Trot$, 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 stresses, scalar local variable) 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 machine accuracy is approximately $1.\mathrm{E}-15$.

2.3 Study of the discretization of time step

One studies the behavior of the integration of the models according to the discretization. For the same modelization, 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:

Computation	T_1	$T_{réf}$ **reference solution**
Many intervals per segment of loading	5	25
Number of total step on the group of way	40 .2 00	

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

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

3 Modelization A

3.1 Characteristic of the modelization

the behavior tested is BETON_RAG , in 3D.

3.2 Quantities tested and results

Variations max	T_{Pa}	T_{rot}	T_1	$T_{réf}$
$V21$	7.6e-14	4.7e-08	5.7e-11	
$VMIS$	0.1.3e-12	1.8e-05	2.21e-03	
$TRACE$	0.2.0e-12	8.2e-06	1.56e-03	0

4 Modelization B

4.1 Characteristic of the modelization

the behavior tested is BETON_UMLV_FP , in 3D.

4.2 Quantities tested and results

Variations max	T_{Pa}	T_{rot}	T_1	$T_{réf}$
$VMIS$	6.15e-15	2.68e-15	4.25e-04	0.0.0.0.0
$TRACE$			0.0	0

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

5 Modelization C

5.1 Characteristic of the modelization

the behavior tested is BETON_BURGER_FP, in 3D.

5.2 Quantities 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 local variables, because they are the tensorial representation of the strains of creep, therefore the values are related to the selected reference 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
- the results converge with time step, and the diagrams of integration make it possible to use the large ones time step.

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
- the results convergent with time step, and the diagrams of integration make it possible to use the large ones time step.

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