SSNV176 – Identification of model ENDO_ORTH_BETON

Summarized:

One presents here the tests of model ENDO_ORTH_BETON on a single element allowing to identify the parameters of the model. Insofar as it does not exist of empirical formula making it possible to gauge the parameters, the user can use some of the cases tests presented here to adjust its parameters. The study of the parameters of the model is in documentation [R7.01.09]. The 5 tests suggested are the following:

1) tension simple
2) tension simple with control
3) compression simple
4) compression simple with simple
5) control tension, simple compression and a biaxial test

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1 Problem of reference

1.1 Geometry and boundary conditions

the element used is a tetrahedron at a point of gauss. There is thus no problem of homogeneity of the fields in the element.

The conditions of linear blockings and the relations between the nodes which should be applied are summarized on [Figure 1.1-a]. The edges $N0N1$, $N0N2$ and $N0N3$ are length 1.

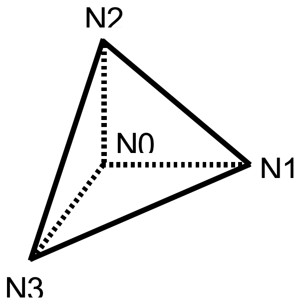
Taking into account the geometry of the element, conditions of blockings and relations linear, the strain is directly connected to displacements of the nodes:

$$\varepsilon_{xx}=DX(N1)$$
$$\varepsilon_{yy}=DY(N2)$$
$$\varepsilon_{zz}=DZ(N3)$$
$$\varepsilon_{xy}=DX(N2)=DY(N1)$$
$$\varepsilon_{xz}=DX(N3)=DZ(N1)$$
$$\varepsilon_{yz}=DY(N3)=DZ(N2)$$

If one works with imposed strain, it is thus enough to impose displacement on the adequate nodes.

If one wishes to work with imposed force, as it is the case for the modelization E, it is necessary to impose the following loadings (see it [Figure 1.1-a] for the definition of the sides $F1$ $F2$, $F3$ and $F4$):

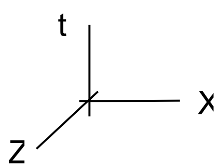
$\sigma_{xx}>0$: FX on $F1$ and $-1/\sqrt{3}FX$ on $F4$, $FX<0$ (tension according to x)
$\sigma_{xx}<0$: FX on $F1$ and $-1/\sqrt{3}FX$ on $F4$, $FX<0$ (compression according to x)
$\sigma_{yy}>0$: FY on $F2$ and $-1/\sqrt{3}FY$ on $F4$, $FY<0$ (tension according to y)
$\sigma_{yy}<0$: FY on $F2$ and $-1/\sqrt{3}FY$ on $F4$, $FY<0$ (compression according to y)
$\sigma_{zz}>0$: FZ on $F3$ and $-1/\sqrt{3}FZ$ on $F4$, $FZ<0$ (tension according to z)
$\sigma_{zz}<0$: FZ on $F3$ and $-1/\sqrt{3}FZ$ on $F4$, $FZ<0$ (compression according to z)



Blockings:
$N0: DX=DY=DZ=0$

Linear relations:
$DY(N1)=DX(N2)$
$DZ(N1)=DX(N3)$
$DZ(N2)=DY(N3)$

Tension/compression in imposed displacement:
According to x DX imposed on $N1$
According to y DY imposed on $N2$
According to z DZ imposed on $N3$



Definition of the sides:
$F1=N0\,N2\,N3$
$F2=N0\,N1\,N3$
$F3=N0\,N1\,N2$
$F4=N1\,N2\,N3$

Tension/compression in imposed force:
According to x : FX on $F1$ and $-1/\sqrt{3}FX$ on $F4$
According to y : FY on $F2$ and $-1/\sqrt{3}FY$ on $F4$
According to x : FZ on $F3$ and $-1/\sqrt{3}FZ$ $F4$

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Figure 1.1-a: Geometry and boundary conditions of the uniaxial tests

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1.2 Material properties

the characteristic materials are identical for the 5 tests which are presented.

The elastic characteristics of the materials are the following ones:

$$E=32000\ Mpa\ ;\ \nu=0.2$$

The breaking stresses in tension and compression are:

$$\sigma_{rupture}^{traction}=3.2\ MPa\ ;\ \sigma_{rupture}^{compression}=-31.8\ MPa$$

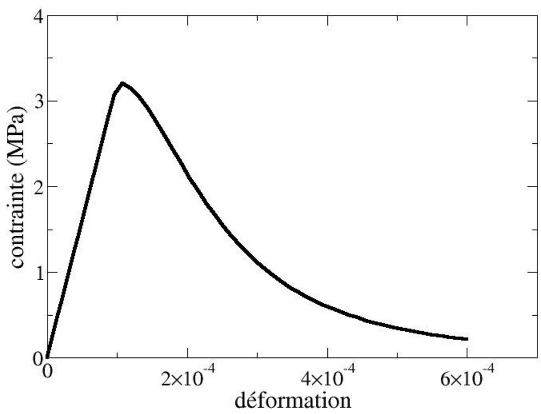
One uses the clearance of parameter following for the constitutive law:

$ALPHA$	$K0(Mpa)$	$ECROB(MJ/m^3)$	$ECROD(MJ/m^3)$	$K_1(Mpa)$	K_2
0.87	3.10-4	1.10-3	6.10-2	10.5	6.10-4

Note::

There exist several sets of parameters which provide the same breaking stresses. The parameters were identified so that the envelope of fracture of the biaxial tests does not present swelling (cf Doc. [R7.01.09]).

The responses of the model for the uniaxial tests are represented below.



Appear 1.2-a: Response of model `ENDO_ORTH_BETON` in simple tension

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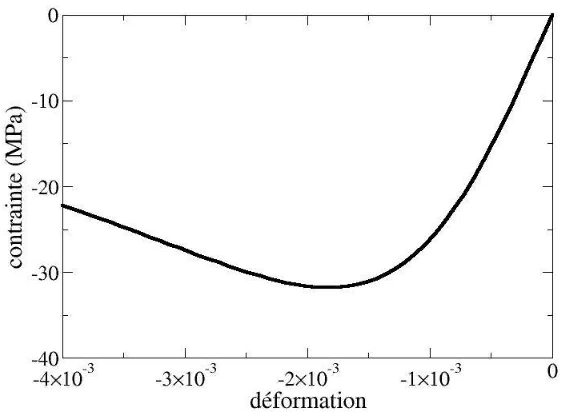

Appears 1.2-b: Response of model ENDO_ORTH_BETON in simple compression

the local variables, which are numbered in Aster, have the following meaning:

$$V1=D_{xx}\,;V2=D_{yy}\,;V3=D_{zz}\,;V4=D_{xy}\,;V5=D_{xz}\,;V6=D_{yz}\,;V7=d\,;$$

Where D is the tensor representing the orthotropic damage of tension, and d is the isotropic damage of compression (cf Doc. [R7.01.09]).

2 Reference solution

This test is a test of non regression.

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3 Modelization A

3.1 Characteristic of the modelization

Modelization 3D

Element MECA_TETRA4.

3.2 Characteristics of the mesh

Many nodes: 4
Number of meshes and types: 1 TETRA4

3.3 Functionalities tested

constitutive law ENDO_ORTH_BETON in simple tension (without control).

3.4 Way of loading

the element is subjected to a uniaxial tension in the direction X. Displacement DX is imposed on the node $N1$.

3.5 Values tested

Urgent	Name of the field	Component	Aster	*Place*
50	DEPL	DX	$N1$	3.E-04
50	EPSI_ELGA	$EPXX$	VOLUME, point 1	3.E-04
50	SIEF_ELGA	$SIXX$	VOLUME, point 1	1.11388E+00
50	VARI_ELGA	$V1(D_{xx})$	VOLUME, point 1	6.59365E-01
50	VARI_ELGA	$V7(d)$	VOLUME, point 1	2.42260E-04

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4 Modelization B

4.1 Characteristic of the modelization

Modelization 3D

Element MECA_TETRA4.

4.2 Characteristics of the mesh

Many nodes: 4

Number of meshes and types: 1 TETRA4

4.3 Functionalities tested

constitutive law ENDO_ORTH_BETON in simple compression (without control of the loading).

4.4 Way of loading

the element is subjected to a uniaxial tension in the direction X. Displacement DX is imposed on the node $N1$.

4.5 Values tested

Urgent	Name of the field	Component	Aster	*Place*
50	DEPL	DX	$N1$	-3.E-03
50	EPSI_ELGA	$EPXX$	VOLUME, point 1	-3.E-03
50	SIEF_ELGA	$SIXX$	VOLUME, point 1	-2.74465E+01
50	VARI_ELGA	$V2(D_{yy})$	VOLUME, point 1	1.30416E-01
50	VARI_ELGA	$V7(d)$	VOLUME, point 1	4.80080E-01

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5 Modelization C

5.1 Characteristic of the modelization

Modelization 3D

Element MECA_TETRA4.

5.2 Characteristics of the mesh

Many nodes: 4
Number of meshes and types: 1 TETRA4

5.3 Functionalities tested

constitutive law ENDO_ORTH_BETON in simple tension (with control of the loading).

5.4 Way of loading

the element is subjected to a uniaxial tension in the direction X. Displacement DX is imposed on the node $N1$. The difference with the modelization A is that one uses the continuation method of loading PRED_ELAS (cf Doc. [R5.03.80]).

5.5 Values tested

Urgent	Name of the field	Component	Aster	***Place***
51	DEPL	DX	$N1$	1.44744E-04
51	EPSI_ELGA	$EPXX$	VOLUME, point 1	1.44744E-04
51	SIEF_ELGA	$SIXX$	VOLUME, point 1	2.89945E+00
51	VARI_ELGA	$V1(D_{xx})$	VOLUME, point 1	2.08793E-01
51	VARI_ELGA	$V7(d)$	VOLUME, point 1	2.30235E-04

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6 Modelization D

6.1 Characteristic of the modelization

Modelization 3D

Element MECA_TETRA4.

6.2 Characteristics of the mesh

Many nodes: 4

Number of meshes and types: 1 TETRA4

6.3 Functionalities tested

constitutive law ENDO_ORTH_BETON in simple compression (with control of the loading).

6.4 Way of loading

the element is subjected to a uniaxial tension in the direction X. Displacement DX is imposed on the node $N1$. The difference with the modelization B is that one uses the continuation method of loading PRED_ELAS (cf Doc. [R5.03.80]).

6.5 Values tested

Urgent	Name of the field	Component	Aster	*Place*
51	DEPL	DX	$N1$	-1.17993E-03
51	EPSI_ELGA	$EPXX$	VOLUME, point 1	-1.17993E-03
51	SIEF_ELGA	$SIXX$	VOLUME, point 1	-2.86498E+01
51	VARI_ELGA	$V2(D_{yy})$	VOLUME, point 1	4.73153E-02
51	VARI_ELGA	$V7(d)$	VOLUME, point 1	1.34312E-01

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7 Modelization E

7.1 Characteristic of the modelization

Modelization `3D`

Element `MECA_TETRA4`.

7.2 Characteristics of the mesh

Many nodes: 4

Number of meshes and types: 1 TETRA4

7.3 Functionalities tested

One tests here constitutive law `ENDO_ORTH_BETON` in 3 cases of loading:

1) U_1 : Simple tension
2) U_2 : Compression
3) U_3 : Biaxial loading (tension in the direction y, compression in the direction x, with a ratio fixes stresses: $\sigma_{yy}=-0.2\sigma_{xx}$

This case test makes it possible to check that the set of parameters chosen by the user respects the following data:

1) breaking stresses in tension,
2) breaking stresses in compression,
3) not swelling of the envelope of fracture for biaxial tests. That consists in checking that the maximum stress in tension σ_{yy} of the biaxial test is lower than the breaking stress in simple tension.

7.4 Way of loading

Unlike the modelizations A, B, C and D, it is the force, and not the displacement, which is imposed here. One uses the continuation method of loading `PRED_ELAS`, because the behavior is lenitive. The following loadings are applied:

- U_1 : FX on $F1$, $-1/\sqrt{3}\,FX$ on $F4$, $FX<0$ (Tension)
- U_2 : FX on $F1$, $-1/\sqrt{3}\,FX$ on $F4$, $FX>0$ (Compression)
- U_3 : FX on $F1$, $-1/\sqrt{3}\,FX$ on $F4$, $FX>0$ (Compression according to the axis x);

FY on $F2$, $-1/\sqrt{3}\,FY$ on $F4$, with $FY=-0{,}2\,FX$ (Tension according to the axis y).

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7.5 Values tested

Urgent	Result	Name of the field	Component	Place	Aster
42	$U1$	SIEF_ELGA	$SIXX$	VOLUME, point 1	3.20684E+00
76	$U2$	SIEF_ELGA	$SIXX$	VOLUME, point 1	-3.18000E+01
74	$U3$	SIEF_ELGA	$SIXX$	VOLUME, point 1	-1.42038E+01

One tests for each computation, the maximum value (in absolute value) of the stress σ_{xx} . One then obtains the breaking stress in tension ($U1$), in compression ($U2$), and one checks that the tensile stress in the biaxial test ($U3$) is lower than the breaking stress in simple tension ($U1$):

1) $U1 : \sigma_{rupture}^{traction}=3.20684\,MPa$
2) $U2 : \sigma_{rupture}^{compression}=-31.8\,MPa$
3) $U3 : \sigma_{U3}^{traction}=-0.2\,\sigma_{U3}^{compression}=0.2\times 14.2038\,Mpa$ and $\sigma_{U3}^{traction}<\sigma_{rupture}^{traction}$

Warning 1 : It may be that the number of time step is insufficient to reach the lenitive phase. The user will thus check that for computations $U1$ and $U2$, computation $U3$ being subjected to an additional warning (cf **warning 2)**, it is well in the lenitive phase (reduction in the parameter of control). The maximum stress in absolute value should not be reached for the last time step. In the contrary case, it is necessary to continue computation until the lenitive phase.

Warning 2: It is possible, for certain set of parameters, to observe difficulties of convergence for computation $U3$ at the time of the lenitive phase. Indeed, the constitutive law ensures the existence and the unicity of the solution in imposed strain, but not in imposed force. These problems of convergence appearing only in the lenitive phase, the user will be able to consider the greatest value of the parameter of control reached, equal to the greatest compressive stress σ_{xx} reached in absolute value, like reference to gauge $K2$. This is true only if there are problems of convergence. If there is no problem of convergence for computation $U3$, and that the maximum stress in absolute value is reached for the last time step, computation should be continued.

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8 Summary of the results

the purpose of the modelizations presented in this document is to identify the parameters of model ENDO_ORTH_BETON. Insofar as it does not exist of empirical formula for the values of the parameters to be used, the user must gauge his parameters step by step on the various tests suggested. The method to gauge the parameters, which is in the document [R7.01.09], can be summarized as follows:

1) choice of $ALPHA$: (0,85 to 0,9),
2) calibration of $K0$, $ECROB$ on the modelizations A, C or E (computation $U1$). Once these gauged parameters, it should not be modified in the phase of calibration of the other parameters,
3) calibration of $K1$, $K2$ and $ECROD$ on the modelizations B (or D) and E. In fact, the modelization E (computations $U2$ and $U3$) is enough. It makes it possible to check the value of the breaking stress in simple compression, and to ensure that the envelope of fracture for biaxial tests does not inflate. It is not necessary to gauge the parameter $K2$ in a very fine way because it rises from a qualitative argument, and no experimental data is never available to identify it.

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