SSNV177 - Test of Willam with the law ENDO_ORTH_BETON

Summary:

One presents here the test of Willam applied to the law of unilateral anisotropic behavior dedicated to the behavior of the concrete ENDO_ORTH_BETON (cf [R7.01.09]) developed in [Feeding-bottle 1]. It is about a test of traction-shearing which makes it possible to in the case of observe the rotation of the clean reference mark of the damage a loading nonproportional.

1 Presentation of the test of Willam

The objective of the test suggested by Willam and al. (cf [Feeding-bottle 2]) is to observe the answer of the model when the clean reference mark of the loading turns. This test is purely theoretical and it is not very probable that experimental results are one day available for this test, taking into account the difficulties dependent under investigation of the rupture of the concrete in traction. Its major interest is to compare the influence of the description of the anisotropy of the damage on the answer of material compared to the isotropic models.
This test is the succession of two phases of loading:

1) First phase: simple traction. One imposes $\Delta\varepsilon_{xx}$ until nonthe linearity, i.e. the beginning of the damage of traction.
2) Second phase: on the basis of the state of deformation at the end of the first phase, one imposes two loadings of traction and a loading of shearing in the loading plan of traction with the following proportionality factors:
$(\Delta\varepsilon_{xx}, \Delta\varepsilon_{yy}, \Delta\varepsilon_{xy})=(0.5, 0.75, 0.5)$.

Figure 1-a we shows the evolution of the various components of the constraint according to the deformation ε_{xx} . One can distinguish 4 phases in the behavior:

1) Phase 1 is the elastic phase under uniaxial loading.
2) Phase 2 corresponds to the growth of the damage in a particular direction. The constraint σ_{xx} decrease insofar as the damage is initiated first of all according to the axis x . The constraint σ_{yy} does not grow linearly, which indicates that the clean reference mark of the damage turns.
3) Phase 3 begins when the damage is total in a direction. The clean reference mark of the damage is then blocked as one sees it on Figure 1-b who shows the evolution of the angle between the clean reference mark of the damage and the initial reference mark (as well as the angle between the clean reference mark of the deformations and the initial reference mark). One observes during this phase 3 an elastic behavior.
4) Phase 4 begins then when the damage in the orthogonal direction with the blocked direction is initiated. One observes a softening of the constraints then generated by the growth of the damage.

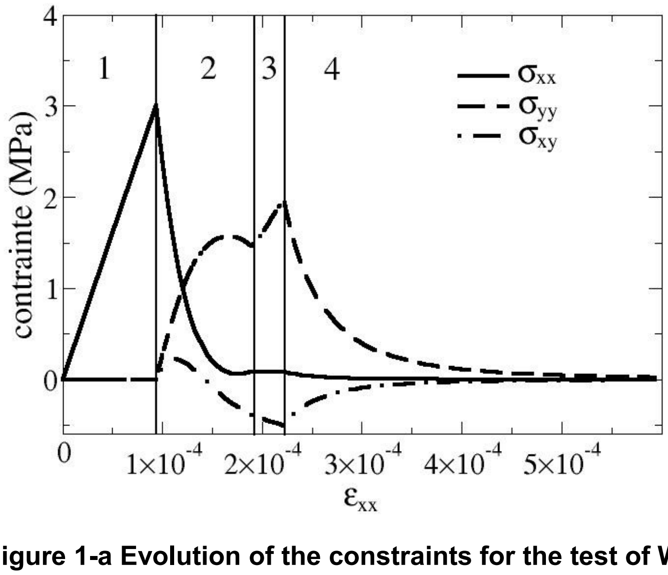


Figure 1-a Evolution of the constraints for the test of Willam

One notices moreover on Figure 1-b that the clean reference mark of the damage does not turn in the same way as the clean reference mark of the deformations. This comes owing to the fact that the law of evolution from the damage is not written according to the deformations but according to the thermodynamic forces, which depend at the same time on the state of deformation and the damage. Insofar as the test of Willam is a theoretical test, it is difficult for us to make a precise assessment on this prediction of the model ENDO_ORTH_BETON.

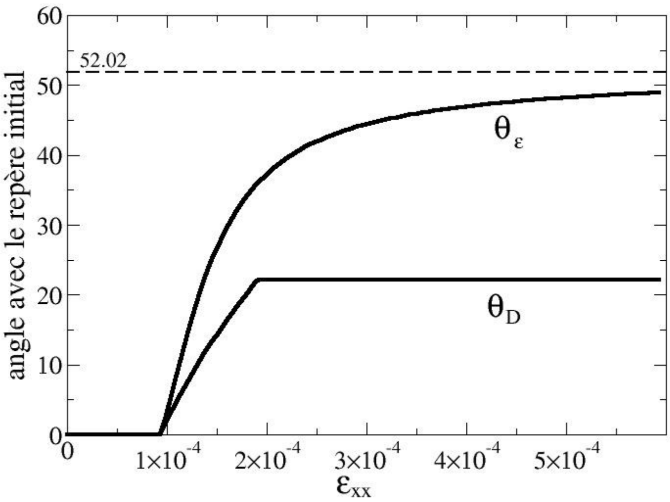


Figure 1-b Evolution of the angles of the clean reference marks of the deformations and of the damage compared to the initial reference mark

The behavior obtained with our model for the test of Willam seems characteristic of until one can wait of the anisotropic models (cf [Feeding-bottle 3]). The principal difference, compared to the results of Carol [1999], lies in the blocking of the clean reference mark which one observes with the model ENDO_ORTH_BETON when the damage is complete in a direction, which does not appear in [Feeding-bottle 3].

2 Problem of reference

2.1 Geometry and boundary conditions

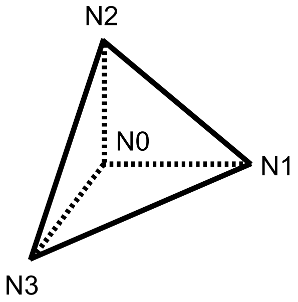
The element used is a tetrahedron at a point of gauss. There is thus no problem of homogeneity of the fields in the element.

The conditions of blockings and the relations linear between the nodes which should be applied are summarized on [the Figure 3]. Edges $N0N1$, $N0N2$ and $N0N3$ are length 1.

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

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

For imposed deformation, it thus suffices to impose displacements on the adequate nodes.



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

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

Loadings :

Phase 1: Traction in imposed displacement
$DX=F^{trac}$ imposed on $N1$

Phase 2: Traction/Shearing in imposed displacement
$DX=DY=0.5*F^{cisa}$ imposed on $N1$
$DY=0.75*F^{cisa}$ imposed on $N2$

Where F^{trac} and F^{cisa} are functions closely connected increasing of time

Figure 2.1-a Geometry, boundary conditions and loadings of the test of Willam

2.2 Material properties

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

The elastic characteristics of materials are the following ones:

$$E=32000\,MPa \quad ; \quad \nu=0.2$$

One uses the set of parameters following for the law of behavior:

$ALPHA$	$K0$ (Mpa)	$ECROB$ (MJ/m^3)	$ECROD$ (MJ/m^3)	K_1 (Mpa)	K_2
0.87	2.634e-4	0	0.06	10.5	6.e-4

3 Reference solution

This test is a test of nonregression.

3.1 Bibliographical references

[1] V. GODARD: Modeling of the anisotropic damage of the concrete with taking into account of the unilateral effect: Application to the digital simulation of the containment systems. Thesis of the University Paris VI, 2005.

[2] K. WILLAM, E. PRAMONO, S. STURE: Fundamental exits of smeared ace models. Proc. Of the SEM-RILEM Int. Conf. One Fractures of Concrete and Rock'n'roll, Shah S.P., Schwartz S.E. (eds), Society of Engineering Mechanics, p. 193-207, 1987.

[3] I. CAROL: Anisotropic ramming evolution using has pseudo-logarithmic tensor missed. Mechanics of heterogeneous materials, Grenoble, 1999.

4 Modeling A

4.1 Characteristics of modeling

Modeling 3D

Element MECA_TETRA4.

4.2 Characteristics of the grid

Many nodes: 4

Many meshs and types: 1 TETRA4

4.3 Way of loading

The loading breaks up into two phases:

- Phase 1: Traction in imposed displacement
  $DX = F^{trac}$ imposed on $N1$
- Phase 2: Traction/Shearing in imposed displacement
  $DX = DY = 0.5 * F^{cisa}$ imposed on $N1$
  $DY = 0.75 * F^{cisa}$ imposed on $N2$

where F^{trac} and F^{cisa} are functions closely connected increasing of time

4.4 Sizes tested and results

The test of nonregression is carried out on the value of the swing angles of the clean reference marks of the deformation and the tensor of damage.

For that, one extracts the fields from deformation (EPSI_ELGA) and of damage (VARI_ELGA) at moment 2, and one creates the matrices (in python) corresponding to the tensors of deformation and damage. Then, one uses the LinearAlgebra library of python to calculate the clean vectors of the matrices associated with the tensors with deformation and damage. Lastly, one calculates the swing angle of these clean vectors compared to the initial reference mark.

Moment	Name of the field	Component	Place	*Aster*
2	EPSI_ELGA	Swing angle of the clean reference mark	$VOLUME$, point 1	45.7160
2	VARI_ELGA	Swing angle of the clean reference mark	$VOLUME$, point 1	23.0825

5 Summary of the results

The test of Willam is a simple test making it possible to compare the influence of the description of the anisotropy of the damage of the law ENDO_ORTH_BETON on the answer of material compared to the isotropic models. It makes it possible moreover to observe the answer of the model when the clean reference mark of the loading turns. One thus notices on the values tested, that the damage does not turn in the same way as the tensor of deformation. Moreover, the swing angle of the tensor of damage reaches a plate when the damage is complete in a direction, which one can associate with the creation of a macro-crack.