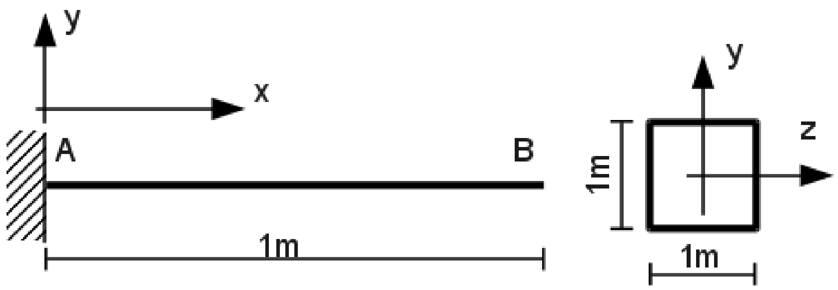
SSNL120 - Cyclic response of models decomportement of the concrete in 1D

Summarized:
In this example one tests the models of behavior of the concrete of Borderie [R7.01.07] and of Mazars [R7.01.08] in their version 1D using a beam element multifibers [R3.08.08] under axial stress. The loading is composed of tension with loading and followed unloading by compression also with loading and unloading. It makes it possible to test strength in tension and compression, to highlight the phenomena of crack reclosing and to test the unelastic strains.

1 General characteristics

1.1 Geometry

Cantilever beam length unit, square section on side unit:



1.2 Material properties

Young's modulus of the concrete: $E=3{,}7272\,10^{10}\,Pa$
Strength in tension of the concrete: $Rt=4.10^{6}\,Pa$
Strength in compression of the concrete: $Rc=40.\,10^{6}\,Pa$

1.3 Boundary conditions

Fixed support in A : $dx=dy=dz=0$ and $drx=dry=drz=0$.

1.4 Loadings

One decreases to grow and the axial strain by imposing a displacement in B the direction x . Two functions are defined, the first requests the material in tension then in compression, the second requests the material in cyclic loading.

Urgent times	n°1 Strain	n°1 n°2	Strain n°2
0	0.00E+00	0	0.00E+00
1	1.40E-04	1	1.40E-04
2	5.00E-05	2	-4.00E-03
3	1.00E-03	3	1.00E-03
4	-4.00E-03	4	-5.00E-03
5	-2.00E-03		
6	-5.00E-03		
7	0.00E+00		

2 Reference solution

For modelization a: the reference solution is the uniaxial response of the constitutive law of Borderie for the materials parameters selected ones. This solution was obtained using the code Eficos (code of multi-layer beams $2D$ [bib1]) in which this model was established.

For modelization b: the reference solution is the uniaxial response of the constitutive law of Mazars for the materials parameters selected ones. This solution is analytical.

3 Bibliography

[GHAVAMIAN HS., MAZARS J.: Strategy of computations simplified for the analysis of the behavior of reinforced concrete structures: code EFICOS. French review of civil engineer 1998; 2: 61 - 90.

4 Modelization A

4.1 Characteristic of the modelization A

longitudinal Mesh of beam: 2 nodes and 1 element (POU_D_EM).
The concrete part of the cross section of the beam is with a grid by 4 fibers.

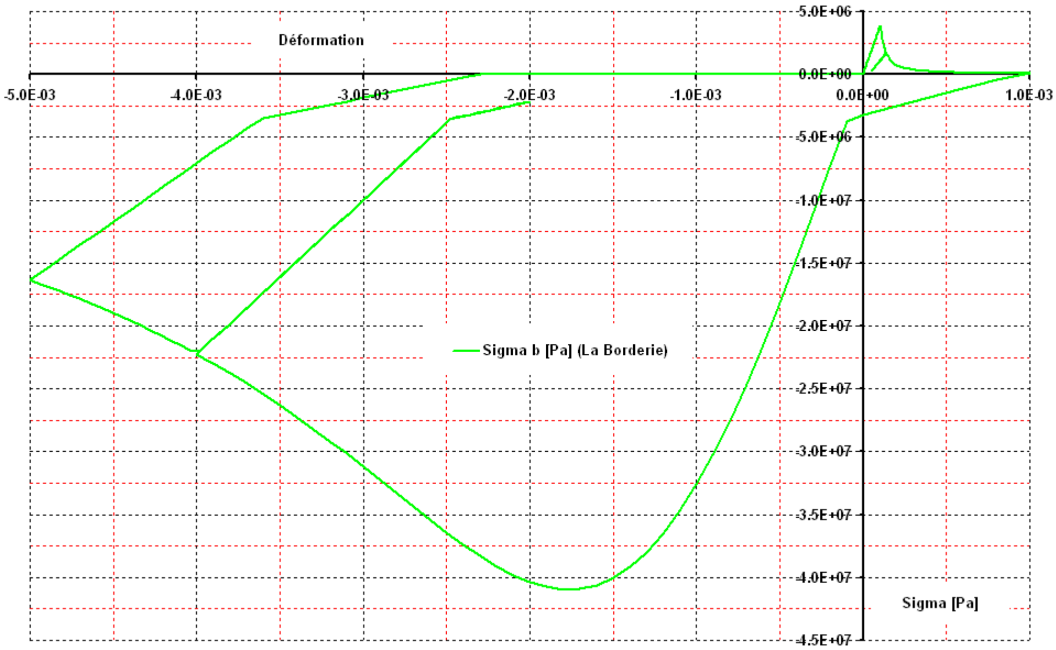
Note:
The problem is 1D, only one fiber could seem sufficient, but that would result in having null terms in the stiffness matrix (the own inertia of fibers not being taken into account) and with an error during the resolution of the system of equations.

The concrete is modelled with the model damage of Christian Borderie in version 1D (LABORD_1D) [R7.01.07]. The material parameters used are the following:

$$Y_{01}=310\,Pa \quad Y_{02}=7000\,Pa \quad A_1=9{,}0.10^{-3}\,Pa^{-1} \quad A_2=5{,}2.10^{-6}\,Pa^{-1}$$
$$B_1=1{,}2 \quad B_2=2{,}0 \quad \beta_1=10^6\,Pa \quad \beta_2=-40.10^6\,Pa \quad \sigma_f=3{,}5.10^6\,Pa$$

4.2 Quantities tested and results

stress-strain curve is represented on the figure below:



One tests the stresses obtained for the strains imposed on the times indicated in paragraph 2, loading n°1:

Standard	time	Reference Reference	Tolerance %
1	1,707816 106	SOURCE_EXTERNE	10-3
2	0,247022 106	SOURCE_EXTERNE	10-3
3	0,068862 106	SOURCE_EXTERNE	10-3
4	– 22,2404 106	SOURCE_EXTERNE	10-3
5	– 2,14356 106	SOURCE_EXTERNE	10-3

One also tests the maximum stresses (tension and compression) and the corresponding strains:

Peaks in Standard	**stress**	***Reference Reference***	**Tolerance %**
Forced			
Tension	3,86138 106	SOURCE_EXTERNE	10-3
Strain	1,036 10-4		10-3
Forced			
Compression	– 40,9496 106	SOURCE_EXTERNE	10-3
Strain	– 1,8.10-3		10-3

5 Modelization B

5.1 Characteristic of the modelization

longitudinal Mesh of beam: 2 nodes and 1 element (POU_D_EM).
The concrete part of the cross section of the beam is with a grid by 4 fibers.

Note:

The problem is 1D , only one fiber could seem sufficient, but that would result in having null terms in the stiffness matrix (the own inertia of fibers not being taken into account) and with an error during the resolution of the system of equations.

The concrete is modelled with the model damage of MAZARS in version 1D [R7.01.08]. The material parameters used are the following:

Elasticity part:

$E=3.72720\text{E+}10\ Pa$, $NU=2.0\text{E-}01$

Nonlinear Part:

$AC=1.71202987\text{E+}00$ $BC=2.01163780\text{E+}03$ $BT=1.21892353\text{E+}04$
$BETA=1.10\text{E+}00$ $AT=7.00\text{E-}01$ $EPSD0=8.20396008\text{E-}05$
$SIGM\_ELS=35.0\text{E+}06\ Pa$, $EPSI\_ELU=3.5\text{E-}03$

That corresponds to a concrete with:

- a stress peak of compression of 40.963MPa , corresponding to a strain peak of $1.75754\text{E-}03$.
- a stress peak of tension of 3.05778MPa

5.2 Quantities tested and results

the 2 loadings are tested.
The figures below give the responses in stresses and strains to the 2 loadings.

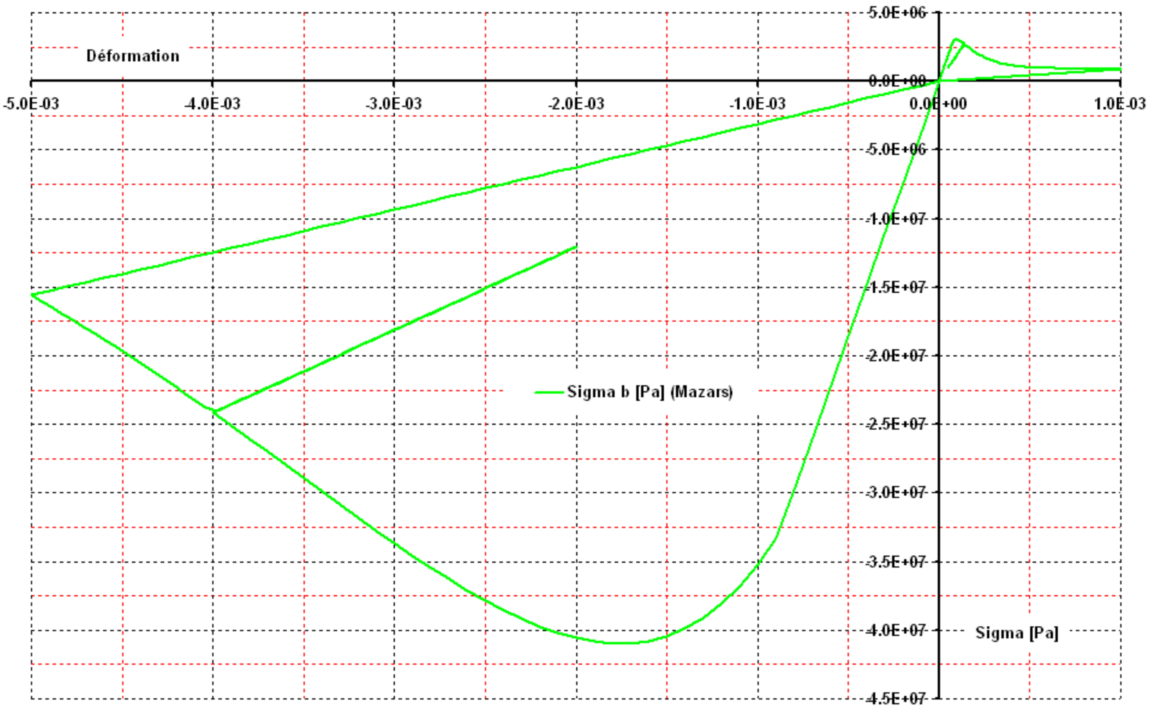


Figure 5.2-a : Evolution the stress according to the strain, loading n°1.

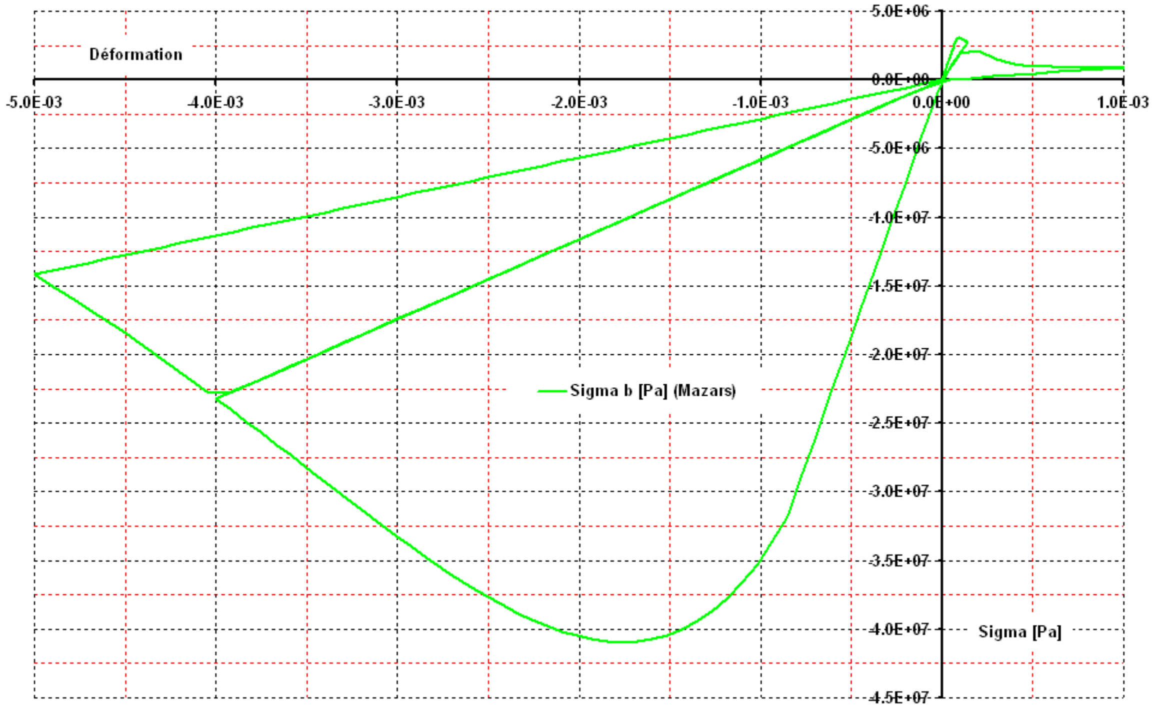
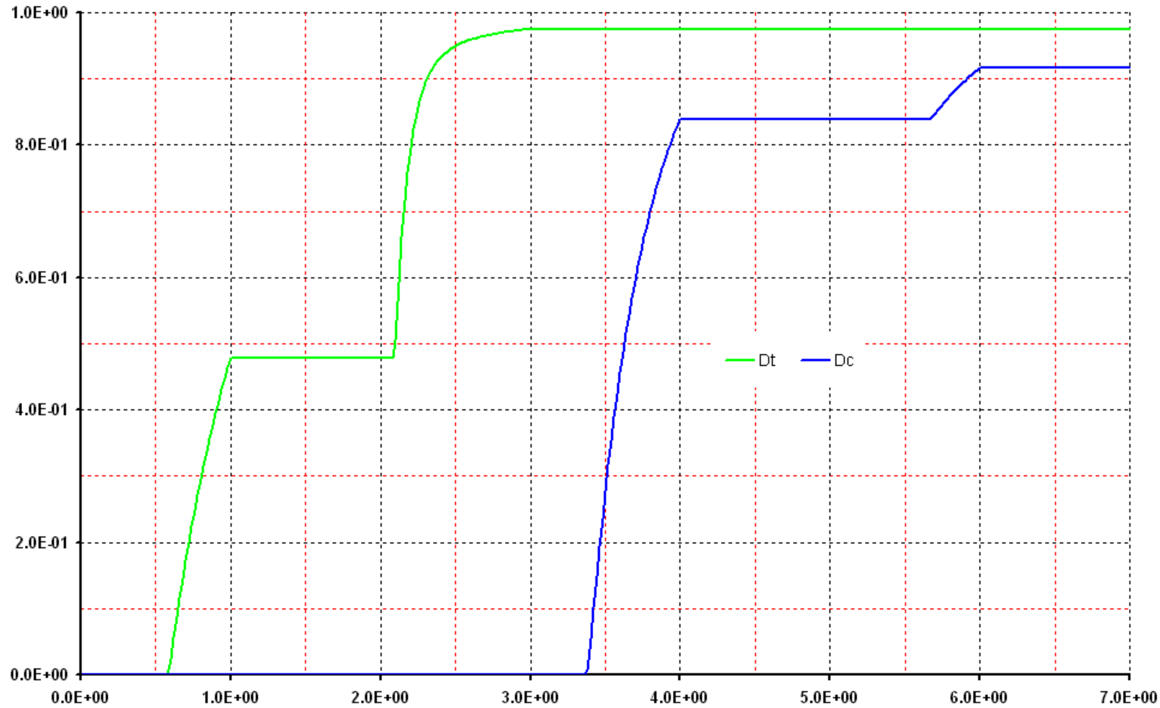
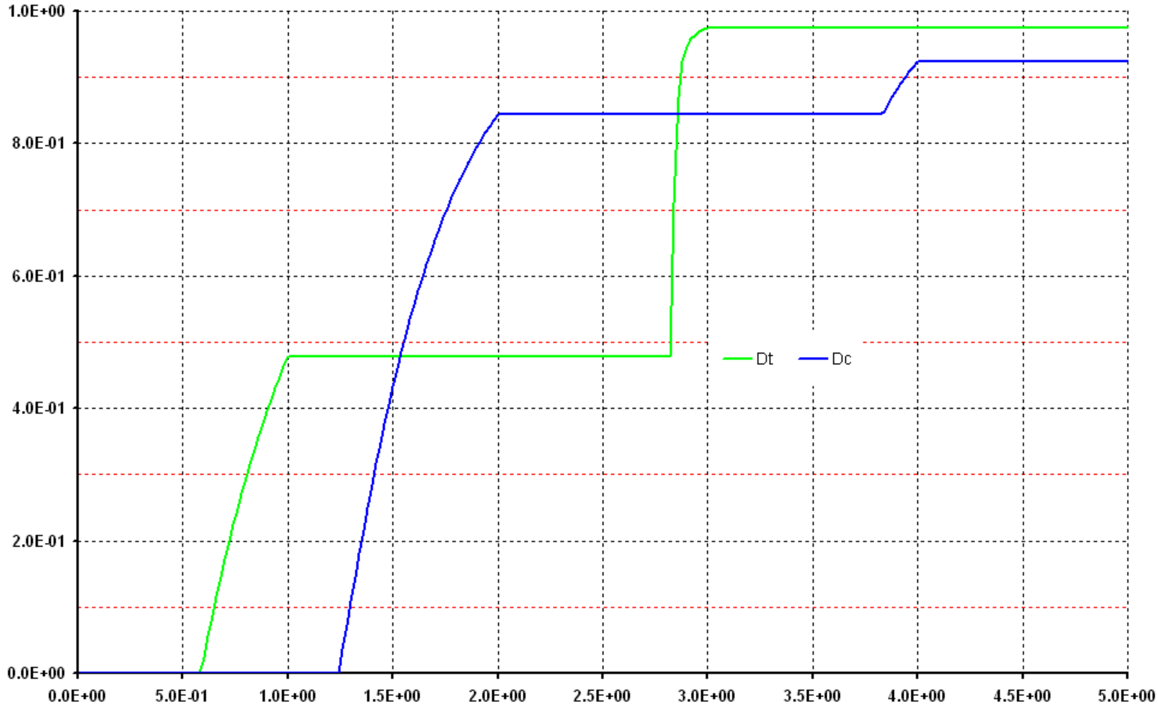


Figure 5.2-b : Evolution loading n°2.

The figures below give the evolutions of the damages.



Appear loading n°1.



Appear of the damages, loading n° 2.

The table below gives for several times the stress, the damage of tension and compression, for the loading n°1. These values are analytical.

Time	Standard size	Reference	Reference	Tolerance
0.60	SIXX	ANALYTIQUE	3.0572E+06	1.00E-04
0.60	Dt	ANALYTIQUE	2.3500E-02	2.00E-03
0.60	cd.	ANALYTIQUE	0.0000E+00	2.00E-03
1.00	SIXX	ANALYTIQUE	2.7195E+06	1.00E-04
1.00	Dt	ANALYTIQUE	4.7880E-01	2.00E-03
1.00	cd.	ANALYTIQUE	0.0000E+00	2.00E-03
2.00	SIXX	ANALYTIQUE	9.7120E+05	1.00E-04
2.00	Dt	ANALYTIQUE	4.7880E-01	2.00E-03
2.00	cd.	ANALYTIQUE	0.0000E+00	2.00E-03
2.10	SIXX	ANALYTIQUE	2.6735E+06	1.00E-04
2.10	Dt	ANALYTIQUE	5.0530E-01	2.00E-03
2.10	cd.	ANALYTIQUE	0.0000E+00	2.00E-03
3.00	SIXX	ANALYTIQUE	9.1770E+05	1.00E-04
3.00	Dt	ANALYTIQUE	9.7540E-01	2.00E-03
3.00	cd.	ANALYTIQUE	0.0000E+00	2.00E-03
0.00	SIXX	ANALYTIQUE	-4.0949E+07	1.00E-04
3.56	Dt	ANALYTIQUE	9.7540E-01	2.00E-03
3.56	cd.	ANALYTIQUE	3.8960E-01	2.00E-03
4.00	SIXX	ANALYTIQUE	-2.3220E+07	1.00E-04
4.00	Dt	ANALYTIQUE	9.7540E-01	2.00E-03
4.00	cd.	ANALYTIQUE	8.4430E-01	2.00E-03
5.00	SIXX	ANALYTIQUE	-1.1610E+07	1.00E-04
5.00	Dt	ANALYTIQUE	9.7540E-01	2.00E-03
5.00	cd.	ANALYTIQUE	8.4430E-01	2.00E-03
5.68	SIXX	ANALYTIQUE	-2.2827E+07	1.00E-04
5.68	Dt	ANALYTIQUE	9.7540E-01	2.00E-03
5.68	cd.	ANALYTIQUE	8.4840E-01	2.00E-03
6.00	SIXX	ANALYTIQUE	-1.4181E+07	1.00E-04
6.00	Dt	ANALYTIQUE	9.7540E-01	2.00E-03
6.00	cd.	ANALYTIQUE	9.2390E-01	2.00E-03

the table below gives for several times criterion ELS, the loading n°1. These values are analytical.

Time	Standard size	Reference	Reference	Tolerance
0.60	V1 = CRITELS	ANALYTIQUE	0.00000	2.00000E-03
1.00	V1 = CRITELS	ANALYTIQUE	0.00000	2.00000E-03
2.00	V1 = CRITELS	ANALYTIQUE	0.00000	2.00000E-03
2.10	V1 = CRITELS	ANALYTIQUE	0.00000	2.00000E-03
3.00	V1 = CRITELS	ANALYTIQUE	0.00000	2.00000E-03
3.56	V1 = CRITELS	ANALYTIQUE	1.16997	2.00000E-03
4.00	V1 = CRITELS	ANALYTIQUE	0.66344	2.00000E-03
5.00	V1 = CRITELS	ANALYTIQUE	0.33172	2.00000E-03
5.68	V1 = CRITELS	ANALYTIQUE	0.65220	2.00000E-03
6.00	V1 = CRITELS	ANALYTIQUE	0.40517	2.00000E-03

the table below gives for several time S L E criterion ELU, for the loading n°1. These values are analytical.

Time	Standard size	Reference	Reference	Tolerance
1.00	V2 = CRITELU	ANALYTIQUE	0.00000	2.00000E-03
2..00	V2 = CRITELU	ANALYTIQUE	0.00000	2.00000E-03
3..00	V2 = CRITELU	ANALYTIQUE	0.00000	2.00000E-03
4..00	V2 = CRITELU	ANALYTIQUE	1.14286	2.00000E-03
4..00	V2 = CRITELU	ANALYTIQUE	0.57143	2.00000E-03
6..00	V2 = CRITELU	ANALYTIQUE	1.42857	2.00000E-03
7..00	V2 = CRITELU	ANALYTIQUE	0.00000	2.00000E-03

the table below gives for several times the stress, the damage of tension and compression, for the loading n°2. These values are analytical.

Time	Standard size	Reference	Reference	Tolerance
1.00	SIXX	ANALYTIQUE	2.7195E+06	1.00E-04
1.00	Dt	ANALYTIQUE	4.7880E-01	2.00E-03
1.00	cd.	ANALYTIQUE	0.0000E+00	2.00E-03
2.00	SIXX	ANALYTIQUE	-2.3220E+07	1.00E-04
2.00	Dt	ANALYTIQUE	4.7880E-01	2.00E-03
2.00	cd.	ANALYTIQUE	8.4430E-01	2.00E-03
3.00	SIXX	ANALYTIQUE	9.1770E+05	1.00E-04
3.00	Dt	ANALYTIQUE	9.7540E-01	2.00E-03
3.00	cd.	ANALYTIQUE	8.4430E-01	2.00E-03
4.00	SIXX	ANALYTIQUE	-1.4181E+07	1.00E-04
4.00	Dt	ANALYTIQUE	9.7540E-01	2.00E-03
4.00	cd.	ANALYTIQUE	9.2390E-01	2.00E-03

the table below gives for several time S L E criterion ELS, for the loading n° 2. These values are analytical.

Time	Standard size	Reference	Reference	Tolerance
1.00	V1 = CRITELS	ANALYTIQUE	0.00000	1.00000E-04
2.00	V1 = CRITELS	ANALYTIQUE	0.66344	1.00000E-04
3.00	V1 = CRITELS	ANALYTIQUE	0.00000	1.00000E-04
4.00	V1 = CRITELS	ANALYTIQUE	0.40517	1.00000E-04

the table below gives for several time S L E criterion EL U, for the loading n° 2. These values are analytical.

Time	Standard size	Reference	Reference	Tolerance
1.00	V2 = CRITELU	ANALYTIQUE	0.00000	2.00000E-03
2.00	V2 = CRITELU	ANALYTIQUE	1.14286	2.00000E-03
3.00	V2 = CRITELU	ANALYTIQUE	0.00000	2.00000E-03
4.00	V2 = CRITELU	ANALYTIQUE	1.42857	2.00000E-03

6 Summary of the results

For the modelization A, the results got with *Code_Aster* is in very good agreement with those of code EFICOS.

For the modelization B, the results are in very good agreement with the analytical values.