# SSNS105 – Nonlinear behavior of a tablecloth of reinforcements

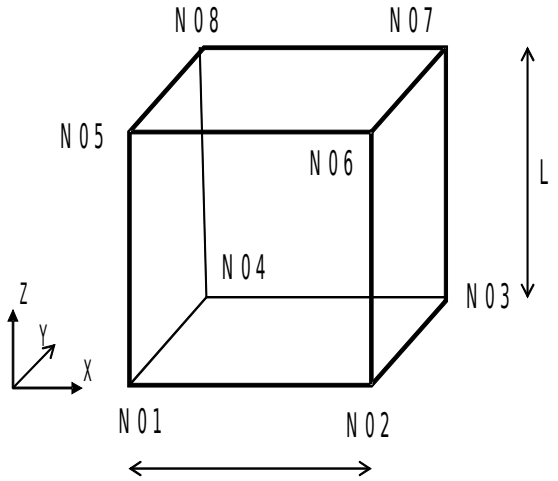
**Summary:**

The objective of this test is to validate modelings grille_membrane and grille_excentre for tablecloths of reinforcements. The reinforced concrete model is subjected to a loading of imposed displacements: ddl_impo. The non-linear behavior of the tablecloths of reinforcement is modelled by GRILLE_ISOT_LINE for plasticity with isotropic work hardening.

# 1 Problem of reference

## 1.1 Geometry

One considers a reinforced concrete cube of with dimensions $L=1\,m$ .




The tablecloths of reinforcements belong to the plan defined by the four nodes $N05-N02-N03-N08$ .
Two tablecloths of reinforcements are defined: a following local direction $X$ and a following local direction $Y$ .

The rate of reinforcement for each tablecloth of reinforcement is of $0.1\,m^2/ml$ (Section per linear meter).

## 1.2 Characteristics of modelings

The concrete mesh is modelled with an element HEXA8.
The modelings considered for the tablecloths of reinforcement are:
- modeling A (§3): use of GRILLE_MEMBRANE with meshs of support TRIA3
- modeling B (§4): use of GRILLE_MEMBRANE with meshs of support QUAD4
- modeling C (§5): use of GRILLE_EXCENTRE with meshs of support TRIA3

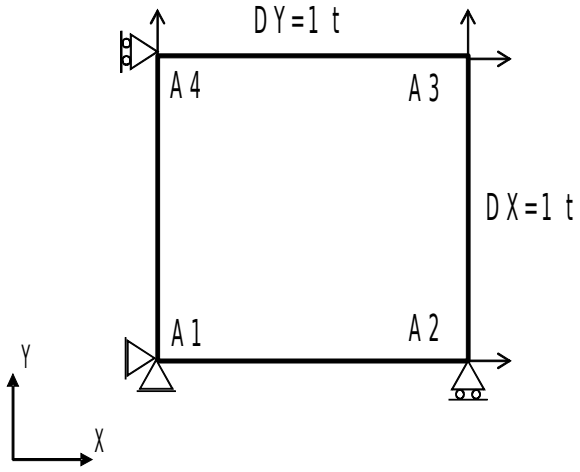
## 1.3 Properties of materials

The concrete material is elastic isotropic whose properties are:
- $E_b=20\,000\,MPa$
- $\nu=0.2$

The law of behavior of the reinforcements follows an elastoplastic model whose properties are:
- $E_a=200\,000\,MPa$
- $\nu=0$
- $E_{ecr}^{acier}=20\,000\,MPa$
- $\sigma_e^{acier}=200\,000\,MPa$

The model GRILLE_ISOT_LINE for plasticity with isotropic work hardening is used in STAT_NON_LINE.

## 1.4 Boundary conditions and loadings




Boundary conditions:

- Embedding in $A1$
- $DX=0$ on the edge $A1-A4$
- $DY=0$ on the edge $A1-A2$
- $DZ=0$ on the lower surface of the cube (N01-N02-N03-N04)

Loading by imposed displacements:

- $DX=1$ on the edge $A2-A3$
- $DY=1\,t$ on the edge $A3-A4$

where $t$ is the parameter of pseudo-time.

## 1.5 Initial conditions

At the beginning displacements and the constraints are worth zero everywhere.

# 2 Reference solution

## 2.1 Method of calculating

The results of reference are got by another calculation Aster.

## 2.2 Sizes and results of reference

One evaluates displacements, the forces of reactions to various nodes of the grid, as well as the value local of constraints for various meshs.

These values are obtained for three moments $t$ : formula formulates $t=1$ , formula formulates $t=2$ , formula formulates $t=10$ .

| Identification | Type of reference | Value of reference | |
|---|---|---|---|
| | | Moment | Value |
| Not formula $N05$ Displacement formula $DZ$ | 'AUTRE_ASTER' | 1 | -7,06E-01 |
| | | 2 | -1,41E+00 |
| | | 10 | -6,50E+00 |
| Not formula $N06$ Displacement formula $DZ$ | 'AUTRE_ASTER' | 1 | -4,81E-01 |
| | | 2 | -9,63E-01 |
| | | 10 | -4,86E+00 |
| Not formula $N01$ Nodal force formulates $DX$ | 'AUTRE_ASTER' | 1 | -6,35E+09 |
| | | 2 | -1,27E+10 |
| | | 10 | -6,33E+10 |
| Not formula $N01$ Nodal force formulates $DY$ | 'AUTRE_ASTER' | 1 | -6,07E+09 |
| | | 2 | -1,21E+10 |
| | | 10 | -6,12E+10 |
| Not formula $N01$ Nodal force formulates $DZ$ | 'AUTRE_ASTER' | 1 | 5,72E+08 |
| | | 2 | 1,14E+09 |
| | | 10 | 4,18E+09 |

Forced in the mesh which models GRILLE_MEMBRANE at the point of Gauss number 1.

| | SIGXX for the meshs of reinforcements directed according to $OX$ | SIGXX for the meshs of reinforcements directed according to $OY$ |
|---|---|---|
| Moment | Value of reference | Value of reference |
| 1 | 2,94E+10 | 2,00E+11 |
| 2 | 5,88E+10 | 2,20E+11 |
| 10 | 2,15E+11 | 3,80E+11 |

Plasticity cumulated in the mesh which models GRILLE_MEMBRANE at the point of Gauss number 1.

| | Internal variables V1 for the meshs of reinforcements directed according to $ox$ | Internal variables V1 for the meshs of reinforcements directed according to $oY$ |
|---|---|---|
| Moment | Value of reference | Value of reference |
| 2 | | 9,00E-01 |
| 10 | 6,73E-01 | 4,06E+04 |

Constraints in the concrete mesh HEXA8 at the point of Gauss number 1: mesh $BMA1$

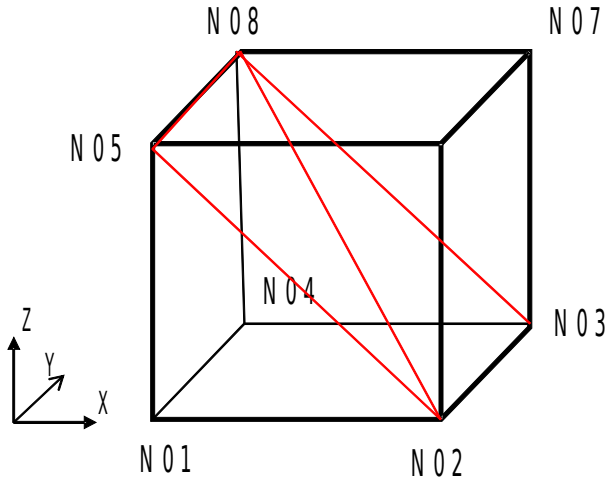
| Moment | Constraints Nets HEXA8 point 1 | | | |
|---|---|---|---|---|
| | Value of reference | | | |
| | SIXX | SIYY | SIZZ | SIXZ |
| 1 | 2,41E+10 | 2,41E+10 | -3,52E+09 | 3,96E+08 |
| 2 | 4,82E+10 | 4,82E+10 | -7,04E+09 | 7,91E+08 |
| 10 | 2,44E+11 | 2,44E+11 | -2,57E+10 | 2,89E+09 |

# 3 Modeling A

## 3.1 Characteristics of modeling

A modeling is used voluminal 3D for the concrete and a model GRILLE_MEMBRANE for the reinforcements whose meshs supports are triangles with 3 nodes.

## 3.2 Characteristics of the grid




Many nodes: 8
Many meshs:

- 1 mesh HEXA8 for the concrete
- 2 meshs TRIA3 for the tablecloths of reinforcements ( $N05-N02-N08$ and $N08-N02-N03$ )

Two models GRILLE_MEMBRANE are defined for the reinforcements (a following the local direction $X$ , a following local direction $Y$ )

## 3.3 Sizes tested and results

| Moment | Field | Component | Place | Reference | Tolerance |
|---|---|---|---|---|---|
| 1 | DEPL | DZ | node: $NO5$ | -7,06E-01 | 0,10% |
| 1 | DEPL | DZ | node: $NO6$ | -4,81E-01 | 0,10% |
| 1 | FORC_NODA | DX | node: $NO1$ | -6,35E+09 | 0,10% |
| 1 | FORC_NODA | DY | node: $NO1$ | -6,07E+09 | 0,10% |
| 1 | FORC_NODA | DZ | node: $NO1$ | 5,72E+08 | 0,10% |
| 1 | SIEF_ELGA | SIXX | mesh: $BMA1$ , not: 1 | 2,00E+11 | 0,10% |
| 1 | SIGM_ELNO | SIXX | mesh: $BMA1$ , not: 1 | 2,00E+11 | 0,10% |
| 1 | SIEF_ELGA | SIXX | mesh: $MA1$ , not: 1 | 2,94E+10 | 0,10% |
| 1 | SIEF_ELGA | SIXX | mesh: $MA3$ , not: 1 | 2,41E+10 | 0,10% |
| 1 | SIEF_ELGA | SIYY | mesh: $MA3$ , not: 1 | 2,41E+10 | 0,10% |
| 1 | SIEF_ELGA | SIZZ | mesh: $MA3$ , not: 1 | -3,52E+09 | 0,10% |
| 1 | SIEF_ELGA | SIXZ | mesh: $MA3$ , not: 1 | 3,96E+08 | 0,10% |

| Moment | Field | Component | Place | Reference | Tolerance |
|---|---|---|---|---|---|
| 2 | DEPL | DZ | Node: *NO5* | -1,41E+00 | 0,10% |
| 2 | DEPL | DZ | node: *NO6* | -9,63E-01 | 0,10% |
| 2 | FORC_NODA | DX | node: *NO1* | -1,27E+10 | 0,10% |
| 2 | FORC_NODA | DY | node: *NO1* | -1,21E+10 | 0,10% |
| 2 | FORC_NODA | DZ | node: *NO1* | 1,14E+09 | 0,10% |
| 2 | SIEF_ELGA | SIXX | mesh: *BMA1* , not: 1 | 2,20E+11 | 0,10% |
| 2 | SIGM_ELNO | SIXX | mesh: *BMA1* , not: 1 | 2,20E+11 | 0,10% |
| 2 | SIEF_ELGA | SIXX | mesh: *MA1* , not: 1 | 5,88E+10 | 0,10% |
| 2 | SIEF_ELGA | SIXX | mesh: *MA3* , not: 1 | 4,82E+10 | 0,10% |
| 2 | SIEF_ELGA | SIYY | mesh: *MA3* , not: 1 | 4,82E+10 | 0,10% |
| 2 | SIEF_ELGA | SIZZ | mesh: *MA3* , not: 1 | -7,04E+09 | 0,10% |
| 2 | SIEF_ELGA | SIXZ | mesh: *MA3* , not: 1 | 7,91E+08 | 0,10% |
| 2 | VARI_ELGA | V1 | mesh: *BMA1* , not: 1 | 9,00E-01 | 0,10% |
| 2 | VARI_ELNO | V1 | mesh: *BMA1* , not: 1 | 9,00E-01 | 0,10% |

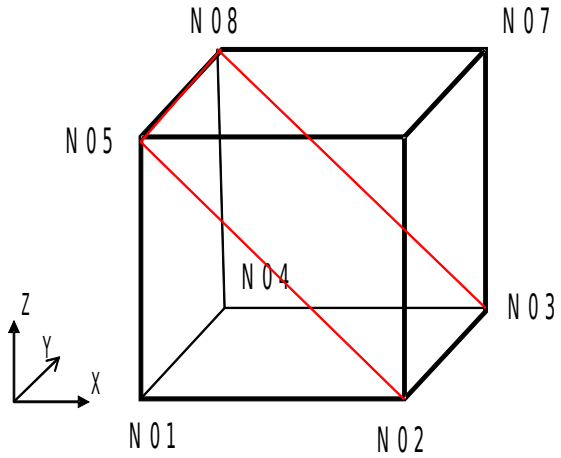
| Moment | Field | Component | Place | Reference | Tolerance |
|---|---|---|---|---|---|
| 10 | DEPL | DZ | node: *NO5* | -6,50E+00 | 0,10% |
| 10 | DEPL | DZ | node: *NO6* | -4,86E+00 | 0,10% |
| 10 | FORC_NODA | DX | node: *NO1* | -6,33E+10 | 0,10% |
| 10 | FORC_NODA | DY | node: *NO1* | -6,12E+10 | 0,10% |
| 10 | FORC_NODA | DZ | node: *NO1* | 4,18E+09 | 0,10% |
| 10 | SIEF_ELGA | SIXX | mesh: *BMA1* , not: 1 | 3,80E+11 | 0,10% |
| 10 | SIGM_ELNO | SIXX | mesh: *BMA1* , not: 1 | 3,80E+11 | 0,10% |
| 10 | SIEF_ELGA | SIXX | mesh: *MA1* , not: 1 | 2,15E+11 | 0,10% |
| 10 | SIEF_ELGA | SIXX | mesh: *MA3* , not: 1 | 2,44E+11 | 0,10% |
| 10 | SIEF_ELGA | SIYY | mesh: *MA3* , not: 1 | 2,44E+11 | 0,10% |
| 10 | SIEF_ELGA | SIZZ | mesh: *MA3* , not: 1 | -2,57E+10 | 0,10% |
| 10 | SIEF_ELGA | SIXZ | mesh: *MA3* , not: 1 | 2,89E+09 | 0,10% |
| 10 | VARI_ELGA | V1 | mesh: *BMA1* , not: 1 | 8,10E+00 | 0,10% |
| 10 | VARI_ELGA | V1 | mesh: *MA1* , not: 1 | 6,73E-01 | 0,10% |
| 10 | VARI_ELNO | V1 | mesh: *MA1* , not: 1 | 6,73E-01 | 0,10% |

# 4 Modeling B

## 4.1 Characteristics of modeling

A voluminal modeling is used 3D for the concrete and a model GRILLE_MEMBRANE for the reinforcements whose meshs supports are quadrangles with four nodes.

## 4.2 Characteristics of the grid




Many nodes: 8
Many meshs:

- 1 mesh HEXA8 for the concrete
- 1 mesh QUAD4 for the tablecloths of reinforcements (N05-N02-N03-N08)
  Two models GRILLE_MEMBRANE are defined for the reinforcements (a following the direction $X$, a following direction $Y$)

## 4.3 Sizes tested and results

| Moment | Field | Component | Place | Reference | Tolerance |
|---|---|---|---|---|---|
| 1 | DEPL | DZ | node: $NO5$ | -7,06E-01 | 0,10% |
| 1 | DEPL | DZ | node: $NO6$ | -4,81E-01 | 0,10% |
| 1 | FORC_NODA | DX | node: $NO1$ | -6,35E+09 | 0,10% |
| 1 | FORC_NODA | DY | node: $NO1$ | -6,07E+09 | 0,10% |
| 1 | FORC_NODA | DZ | node: $NO1$ | 5,72E+08 | 0,10% |
| 1 | SIEF_ELGA | SIXX | mesh: $BMA1$ , not: 1 | 2,00E+11 | 0,10% |
| 1 | SIEF_ELGA | SIXX | mesh: $MA1$ , not: 1 | 2,94E+10 | 0,10% |
| 1 | SIEF_ELGA | SIXX | mesh: $MA3$ , not: 1 | 2,41E+10 | 0,10% |
| 1 | SIEF_ELGA | SIYY | mesh: $MA3$ , not: 1 | 2,41E+10 | 0,10% |
| 1 | SIEF_ELGA | SIZZ | mesh: $MA3$ , not: 1 | -3,52E+09 | 0,10% |
| 1 | SIEF_ELGA | SIXZ | mesh: $MA3$ , not: 1 | 3,96E+08 | 0,10% |

| Moment | Field | Component | Place | Reference | Tolerance |
|---|---|---|---|---|---|
| 2 | DEPL | DZ | node: NO5 | -1,41E+00 | 0,10% |
| 2 | DEPL | DZ | node: NO6 | -9,63E-01 | 0,10% |
| 2 | FORC_NODA | DX | node: NO1 | -1,27E+10 | 0,10% |
| 2 | FORC_NODA | DY | node: NO1 | -1,21E+10 | 0,10% |
| 2 | FORC_NODA | DZ | node: NO1 | 1,14E+09 | 0,10% |
| 2 | SIEF_ELGA | SIXX | mesh: BMA1 , not: 1 | 2,20E+11 | 0,10% |
| 2 | SIEF_ELGA | SIXX | mesh: MA1 , not: 1 | 5,88E+10 | 0,10% |
| 2 | SIEF_ELGA | SIXX | mesh: MA3 , not: 1 | 4,82E+10 | 0,10% |
| 2 | SIEF_ELGA | SIYY | mesh: MA3 , not: 1 | 4,82E+10 | 0,10% |
| 2 | SIEF_ELGA | SIZZ | mesh: MA3 , not: 1 | -7,04E+09 | 0,10% |
| 2 | SIEF_ELGA | SIXZ | mesh: MA3 , not: 1 | 7,91E+08 | 0,10% |
| 2 | VARI_ELGA | V1 | mesh: BMA1 , not: 1 | 9,00E-01 | 0,10% |

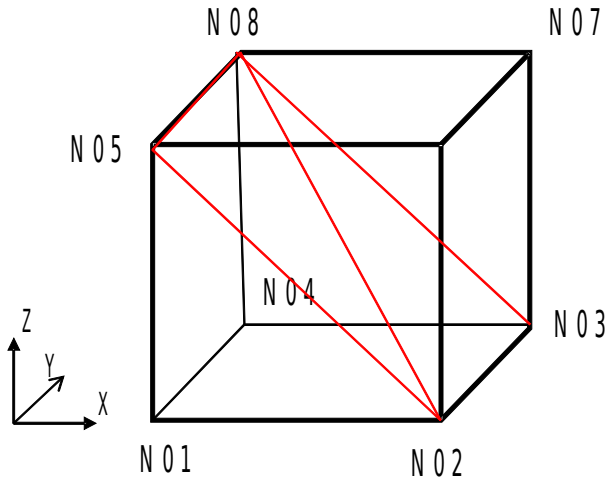
| Moment | Field | Component | Place | Reference | Tolerance |
|---|---|---|---|---|---|
| 10 | DEPL | DZ | node: NO5 | -6,50E+00 | 0,10% |
| 10 | DEPL | DZ | node: NO6 | -4,86E+00 | 0,10% |
| 10 | FORC_NODA | DX | node: NO1 | -6,33E+10 | 0,10% |
| 10 | FORC_NODA | DY | node: NO1 | -6,12E+10 | 0,10% |
| 10 | FORC_NODA | DZ | node: NO1 | 4,18E+09 | 0,10% |
| 10 | SIEF_ELGA | SIXX | mesh: BMA1 , not: 1 | 3,80E+11 | 0,10% |
| 10 | SIEF_ELGA | SIXX | mesh: MA1 , not: 1 | 2,15E+11 | 0,10% |
| 10 | SIEF_ELGA | SIXX | mesh: MA3 , not: 1 | 2,44E+11 | 0,10% |
| 10 | SIEF_ELGA | SIYY | mesh: MA3 , not: 1 | 2,44E+11 | 0,10% |
| 10 | SIEF_ELGA | SIZZ | mesh: MA3 , not: 1 | -2,57E+10 | 0,10% |
| 10 | SIEF_ELGA | SIXZ | mesh: MA3 , not: 1 | 2,89E+09 | 0,10% |
| 10 | VARI_ELGA | V1 | mesh: BMA1 , not: 1 | 8,10E+00 | 0,10% |
| 10 | VARI_ELGA | V1 | mesh: MA1 , not: 1 | 6,73E-01 | 0,10% |

# 5 Modeling C

## 5.1 Characteristics of modeling

A voluminal modeling is used 3D for the concrete and a model GRILLE_EXCENTRE for the reinforcements whose meshs supports are triangles with three nodes.

## 5.2 Characteristics of the grid




Many nodes: 8
Many meshs:

- 1 mesh HEXA8 for the concrete
- 2 meshs TRIA3 for the tablecloths of reinforcements ( $N05-N02-N08$ and $N08-N02-n03$ )
  Two models GRILLE_EXCENTRE are defined for the reinforcements (a following the local direction $X$, a following local direction $Y$ )

To the boundary conditions described in §1.4 the conditions are added $DRX=0$, $DRY=0$, $DRZ=0$
with the nodes N02-N03-NO5-N08.

## 5.3 Sizes tested and results

| Moment | Field | Component | Place | Reference | Tolerance |
|---|---|---|---|---|---|
| 1 | DEPL | DZ | node: $NO5$ | -7,06E-01 | 0,10% |
| 1 | DEPL | DZ | node: $NO6$ | -4,81E-01 | 0,10% |
| 1 | FORC_NODA | DX | node: $NO1$ | -6,35E+09 | 0,10% |
| 1 | FORC_NODA | DY | node: $NO1$ | -6,07E+09 | 0,10% |
| 1 | FORC_NODA | DZ | node: $NO1$ | 5,72E+08 | 0,10% |
| 1 | SIEF_ELGA | SIXX | mesh: $MA1$ , not: 1 | 2,94E+10 | 0,10% |
| 1 | SIEF_ELGA | SIXX | mesh: $MA3$ , not: 1 | 2,41E+10 | 0,10% |
| 1 | SIEF_ELGA | SIZZ | mesh: $MA3$ , not: 1 | -3,52E+09 | 0,10% |
| 1 | SIEF_ELGA | SIXZ | mesh: $MA3$ , not: 1 | 3,96E+08 | 0,10% |

| Moment | Field | Component | Place | Reference | Tolerance |
|---|---|---|---|---|---|
| 2 | DEPL | DZ | node: NO5 | -1,41E+00 | 0,10% |
| 2 | DEPL | DZ | node: NO6 | -9,63E-01 | 0,10% |
| 2 | FORC_NODA | DX | node: NO1 | -1,27E+10 | 0,10% |
| 2 | FORC_NODA | DY | node: NO1 | -1,21E+10 | 0,10% |
| 2 | FORC_NODA | DZ | node: NO1 | 1,14E+09 | 0,10% |
| 2 | SIEF_ELGA | SIXX | mesh: MA1 , not: 1 | 5,88E+10 | 0,10% |
| 2 | SIEF_ELGA | SIXX | mesh: MA3 , not: 1 | 4,82E+10 | 0,10% |
| 2 | SIEF_ELGA | SIZZ | mesh: MA3 , not: 1 | -7,04E+09 | 0,10% |
| 2 | SIEF_ELGA | SIXZ | mesh: MA3 , not: 1 | 7,91E+08 | 0,10% |
| 2 | VARI_ELGA | V1 | mesh: BMA1 , not: 1 | 9,00E-01 | 0,10% |

| Moment | Field | Component | Place | Reference | Tolerance |
|---|---|---|---|---|---|
| 10 | DEPL | DZ | node: NO5 | -6,50E+00 | 0,10% |
| 10 | DEPL | DZ | node: NO6 | -4,86E+00 | 0,10% |
| 10 | FORC_NODA | DX | node: NO1 | -6,33E+10 | 0,10% |
| 10 | FORC_NODA | DY | node: NO1 | -6,12E+10 | 0,10% |
| 10 | FORC_NODA | DZ | node: NO1 | 4,18E+09 | 0,10% |
| 10 | SIEF_ELGA | SIXX | mesh: MA1 , not: 1 | 2,15E+11 | 0,10% |
| 10 | SIEF_ELGA | SIXX | mesh: MA3 , not: 1 | 2,44E+11 | 0,10% |
| 10 | SIEF_ELGA | SIZZ | mesh: MA3 , not: 1 | -2,57E+10 | 0,10% |
| 10 | SIEF_ELGA | SIXZ | mesh: MA3 , not: 1 | 2,89E+09 | 0,10% |
| 10 | VARI_ELGA | V1 | mesh: BMA1 , not: 1 | 8,10E+00 | 0,10% |
| 10 | VARI_ELGA | V1 | mesh: MA1 , not: 1 | 6,73E-01 | 0,10% |

Elastic design

| Moment | Field | Component | Place | Reference | Tolerance |
|---|---|---|---|---|---|
| 1 | DEPL | DZ | node: NO5 | -7,06E-01 | 0,10% |
| 1 | DEPL | DZ | node: NO6 | -4,81E-01 | 0,10% |
| 1 | FORC_NODA | DX | node: NO1 | -6,35E+09 | 0,10% |
| 1 | FORC_NODA | DY | node: NO1 | -6,07E+09 | 0,10% |
| 1 | FORC_NODA | DZ | node: NO1 | 5,72E+08 | 0,10% |
| 1 | SIEF_ELGA | SIXX | mesh: MA1 , not: 1 | 2,94E+10 | 0,10% |
| 1 | SIEF_ELGA | SIXX | mesh: MA3 , not: 1 | 2,41E+10 | 0,10% |
| 1 | SIEF_ELGA | SIZZ | mesh: MA3 , not: 1 | -3,52E+09 | 0,10% |
| 1 | SIEF_ELGA | SIXZ | mesh: MA3 , not: 1 | 3,96E+08 | 0,10% |

# 6 Synthesis

Various modelings of this case test validate it behavior GRILLE_MEMBRANE and GRILLE_EXCENTRE for a complete structure.