SSNL119 - Static response of a reinforced concrete beam (rectangular section) to nonlinear behavior

Summary:

The problem consists in analyzing the answer of a reinforced concrete beam in inflection 3 points until the ruin via a modeling multifibre beamS [R3.08.08] or of a modeling of plate using a reinforced concrete law homogenized. CE test corresponds to a static analysis of a beam having a non-linear behavior. Modelings of the test are:

- modeling A : the concrete is modelled with the lenitive law endommageable of behavior of Mazars in its version 1D [R7.01.08] and ac1st is elastoplastic;
- modeling b: the reinforced concrete beam is modelled with the homogenized law GLRC_DM and a steel grid following an elastoplastic law representing lower steels;
- modeling C: the reinforced concrete beam is modelled with the homogenized law GLRC_DM with a section of realised reinforcement;
- modeling D: the reinforced concrete beam is modelled with the homogenized law DHRC.

1 General characteristics

1.1 Geometry

The beam in inflection three points studied 5m measurement length. Its section is of 0,2x0,5m. Its geometry as well as the positioning of steels which constitute it are defined on Figure 1.1-a.

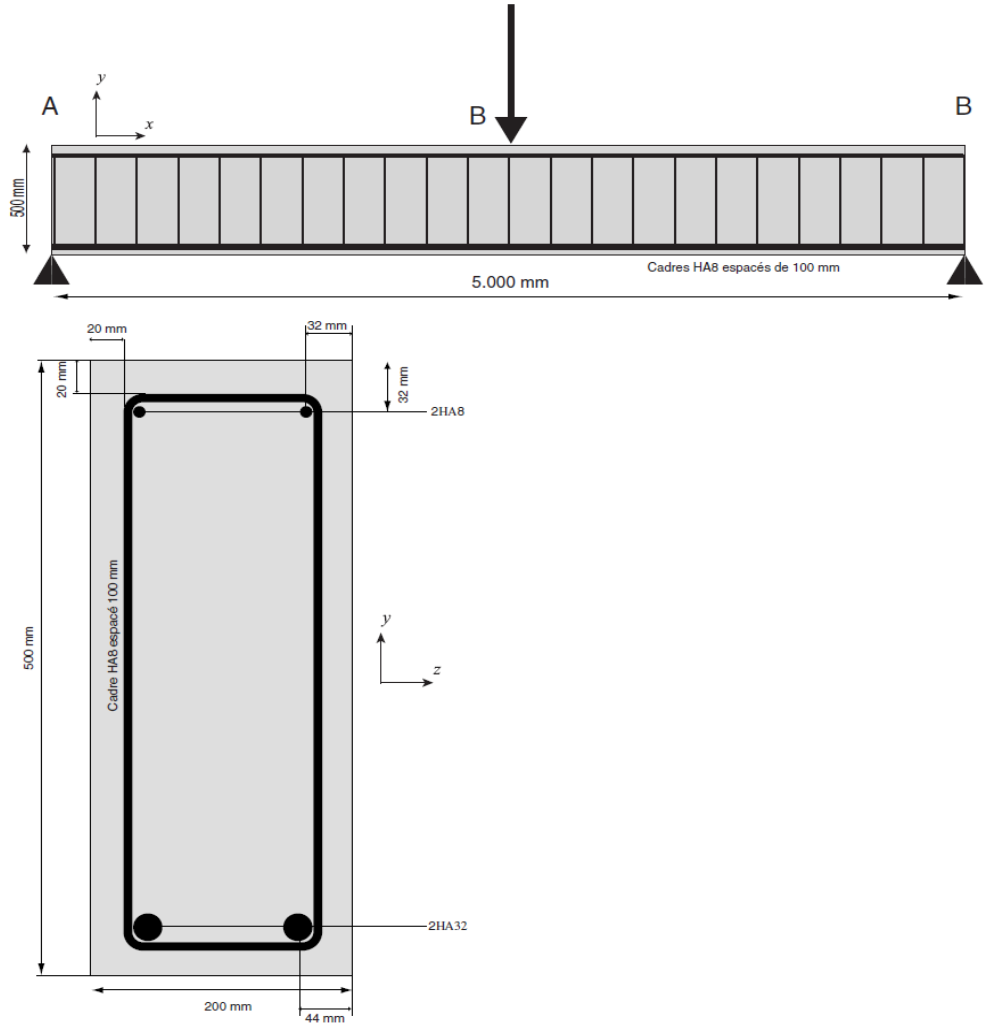

Figure 1.1-a : plan of the beam.

1.2 Material properties

- Béton:
  Young modulus: $E = 37272\,MPa$
  Poisson's ratio: $\nu = 0.2$
  Threshold of elasticity in traction: $\sigma_{ft} = 3.9\,MPa$
  Threshold of elasticity in compression: $\sigma_{fc} = 38.3\,MPa$
  Threshold of elastic strain in compression: $\varepsilon_{fc} = 2.0.10^{-3}$
  Energy of cracking $G_f^1 = 110\,J/m^2$

- Steel:
  Young modulus: $E = 200\,000\,MPa$

Poisson's ratio: $\nu = 0.33$
Yield stress: $\sigma_e = 400\ MPa$
Tangent module (plastic slope) $E_T = 3280\ MPa$

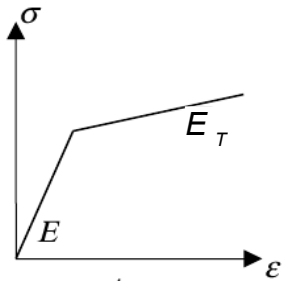

Figure 1.2-a : Courbe of stress-strain of steel

1.3 Boundary conditions and loadings

Simple support in B : $DY = 0$.
Support doubles in A : $DX = DY = DZ = 0$ just as $DRX = DRY = 0$.

Quasi-static loading: monotonous displacement DY to the bottom applied to mid--span in C (deflection test 3 points), according to a linear function of time:

t	DY
0,0	$0{,}0\ cm$
3,0	$-3{,}0\ cm$
5,0	$-5{,}0\ cm$

The final displacement applied for modeling A is of $-3{,}0\ cm$.

For modeling D, imposed displacement is done according to DZ .

Note: the transverse reinforcements are not taken into account in calculations.

2 Reference solution

This test validates the not-regression.
For modelings of B with D, the results are also compared with the experimental results resulting from [1] and [2].

2.1 Bibliographical references

[1] Pera, J. (1973). 'Reinforced concrete redundant beams. Experimental Theoretical and analysis'. Thesis by has doctor-engineer, INSA Lyon.

[2] GHAVAMIAN HS., DELAPLACE A., Models of concrete cracking (Project MECA). French review of civil engineer, volume 7 – n°5/2003.

3 Modeling A

3.1 Characteristics of modeling

The concrete is modelled with the law of damage of Mazars in version 1D (MAZARS_GC) [R7.01.08]. Parameters materials used are the following:

$$AC = 1.71202987 \quad BC = 2.01163780\text{E}+03 \quad BT = 1.21892353\text{E}+04 \quad BETA = 1.10\text{E}+00$$
$$AT = 1.0\text{E}+00 \quad EPSD0 = 8.20396008\text{E}-05$$

3.2 Sizes tested and results

The arrow is that of the center of the beam, the local results (forced, deformations) are those of the second point of Gauss of the 9ème element (nearest to the medium of the beam).

Reaction of support at the point A :

Arrow (m)	Size	Place	Standard reference	Tolerance
1,00E-03	REAC_NODA	DY group: With	NON_REGRESSION	3 . 0E -0 4
1.40E-02	REAC_NODA	DY group: With	NON_REGRESSION	3.0E-04
2.68E-02	REAC_NODA	DY group: With	NON_REGRESSION	3.0E-04

Constraint in tended steels:

Arrow (m)	Size	Place	Standard reference	Tolerance
1,00E-03	SIXX	mesh: M9, not: 2 sous_point: 41	NON_REGRESSION	3.0E-04
1.40E-02	SIXX	mesh: M9, not: 2 sous_point: 41	NON_REGRESSION	3.0E-04
2.68E-02	SIXX	mesh: M9, not: 2 sous_point: 41	NON_REGRESSION	0,0E+00

Constraint in compressed steels:

Arrow (m)	Size	Place	Standard reference	Tolerance
1,00E-03	SIXX	mesh: M9, not: 2 sous_point: 44	NON_REGRESSION	3.0E-04
1.40E-02	SIXX	mesh: M9, not: 2 sous_point: 44	NON_REGRESSION	3.0E-04
2.68E-02	SIXX	mesh: M9, not: 2 sous_point: 44	NON_REGRESSION	3.0E-04

Deformation in tended steels:

Arrow (m)	Size	Place	Standard reference	Tolerance
1,00E-03	EPXX	mesh: M9, not: 2 sous_point: 41	NON_REGRESSION	3.0E-04
1.40E-02	EPXX	mesh: M9, not: 2 sous_point: 41	NON_REGRESSION	3.0E-04
2.68E-02	EPXX	mesh: M9, not: 2 sous_point: 41	NON_REGRESSION	3.0E-04

Constraint in the compressed concrete:

Arrow (m)	Size	Place	Standard reference	Tolerance
1,00E-03	SIXX	mesh: M9, not: 2 sous_point: 1	NON_REGRESSION	3.0E-04
1.40E-02	SIXX	mesh: M9, not: 2 sous_point: 1	NON_REGRESSION	3.0E-04
2.68E-02	SIXX	mesh: M9, not: 2 sous_point: 1	NON_REGRESSION	3.0E-04

Constraint in the tended concrete:

Arrow (m)	Size	Place	Standard reference	Tolerance
1,00E-03	SIXX	mesh: M9, not: 2 sous_point: 40	NON_REGRESSION	3.0E-04
1.40E-02	SIXX	mesh: M9, not: 2 sous_point: 40	NON_REGRESSION	3.0E-04
2.68E-02	SIXX	mesh: M9, not: 2 sous_point: 40	NON_REGRESSION	3.0E-04

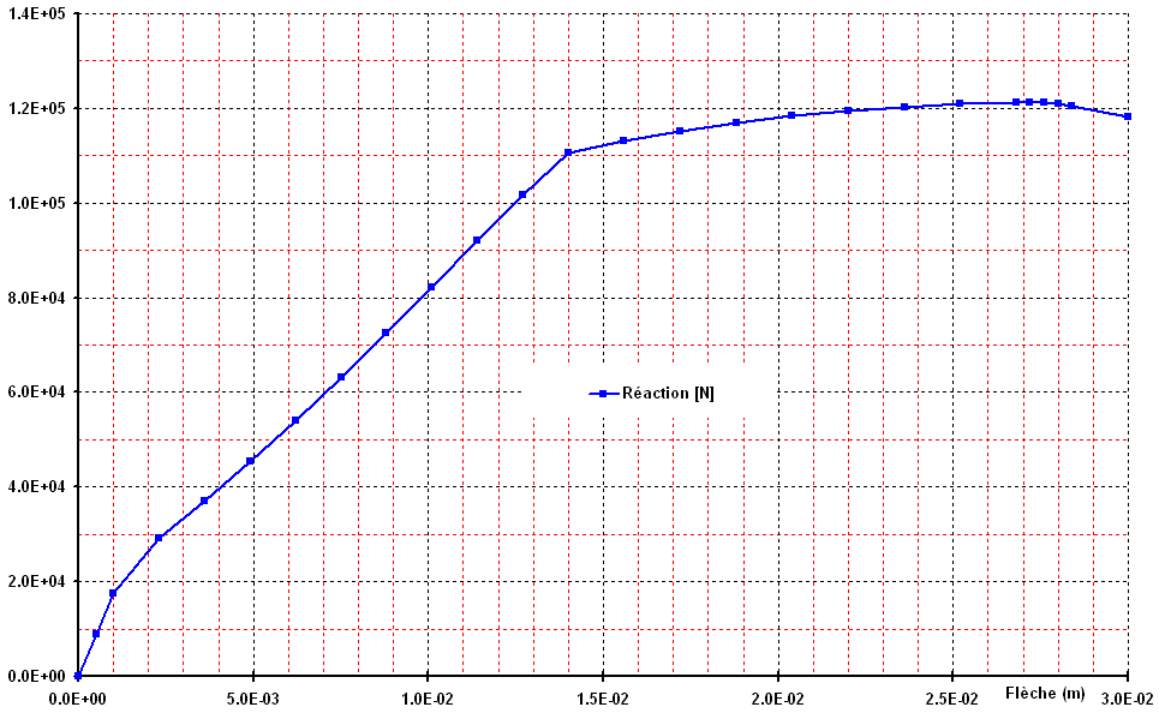

Figure 3.2-a : Réaction on a support, according to the arrow in the center.

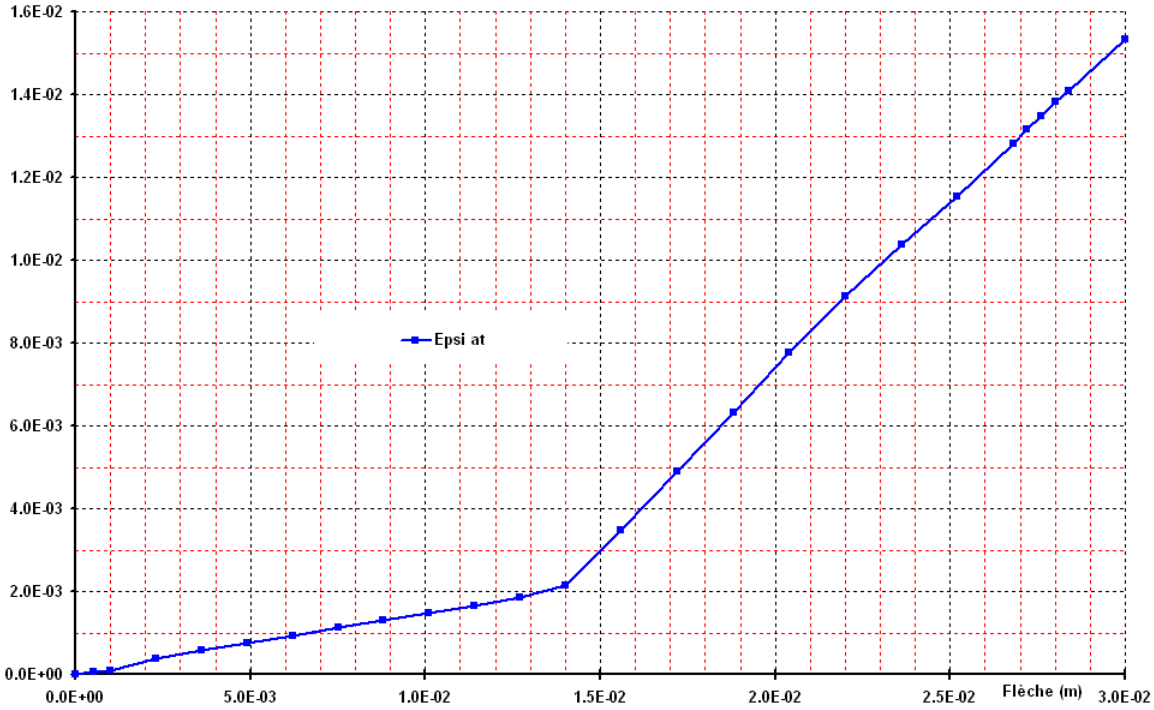

Figure 3.2-b : Deformation of tended steels, according to the arrow in the center.

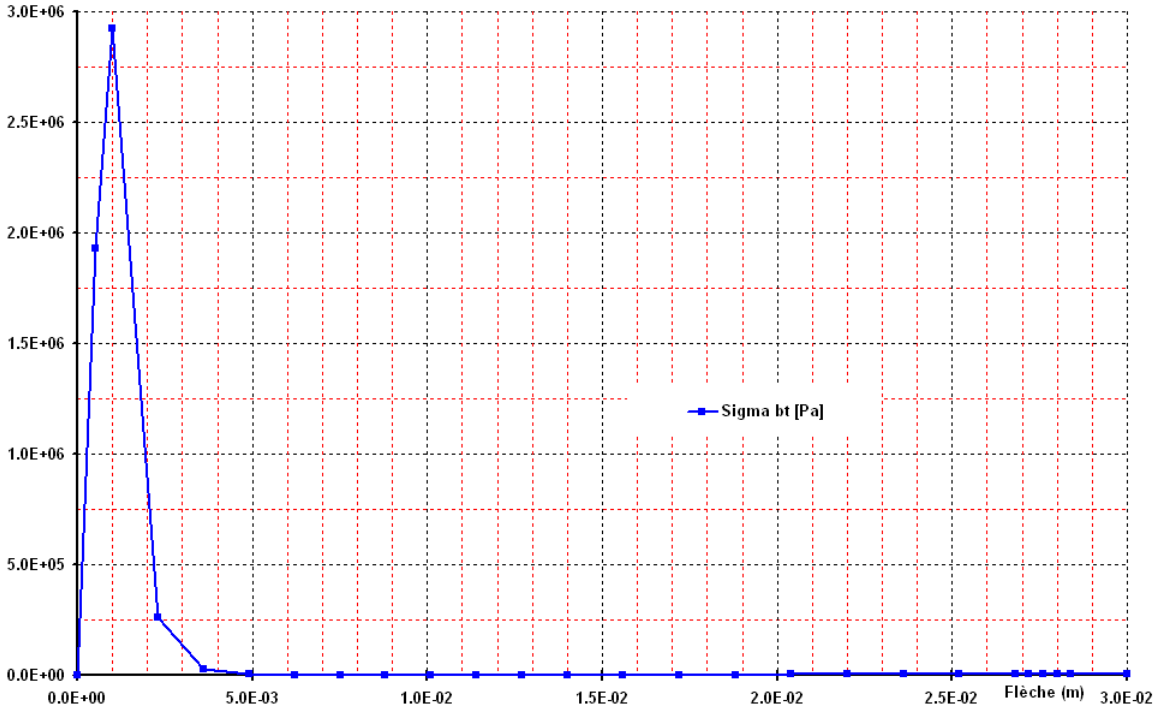

Figure 3.2-c : Contrainte tended concrete, according to the arrow in the center.

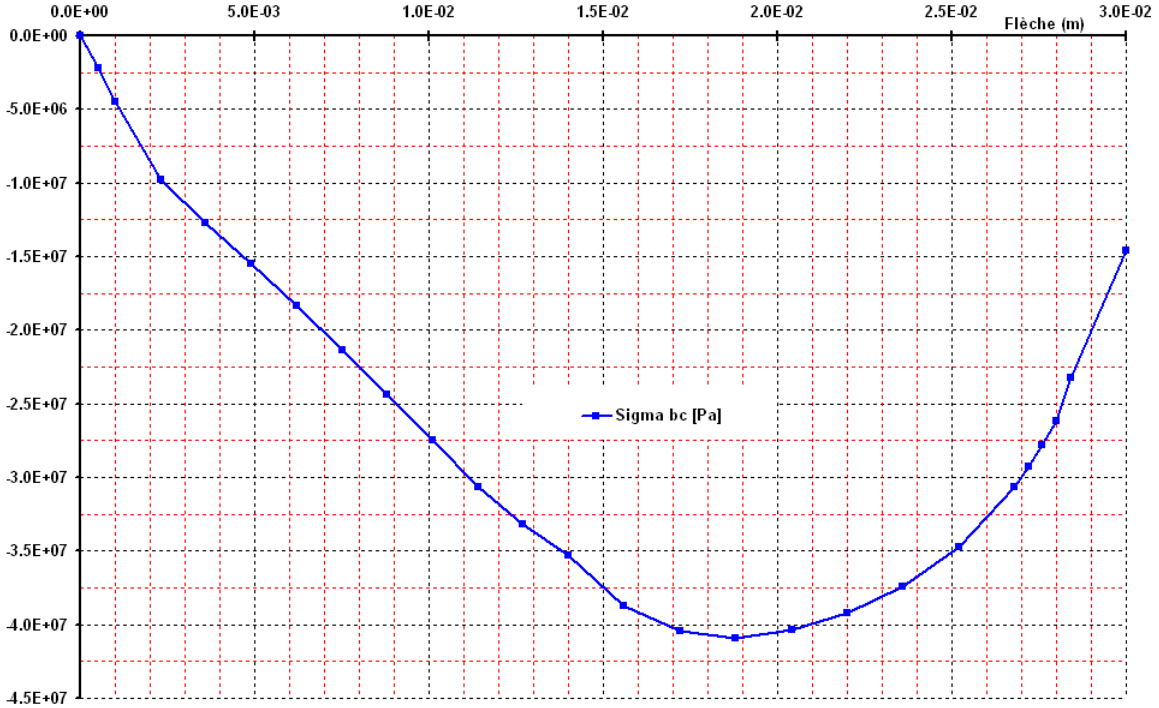

Figure 3.2-d : Contrainte compressed concrete, according to the arrow in the center.

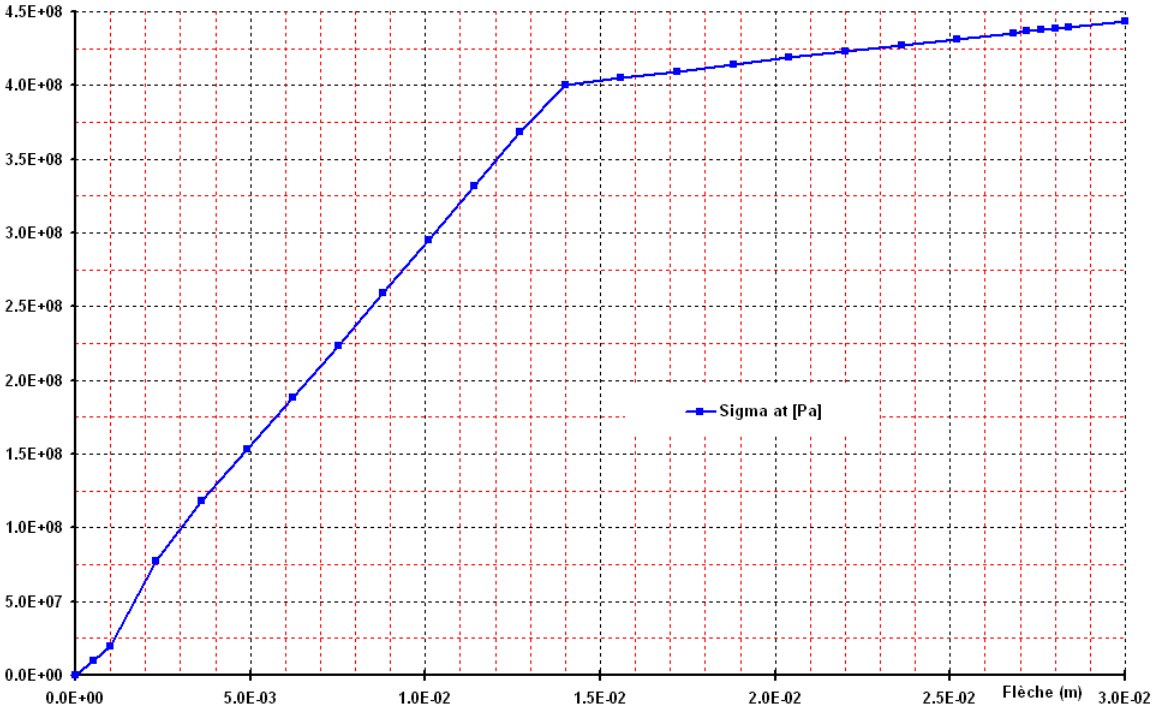

Figure 3.2-e : Contrainte tended steel, according to the arrow in the center.

3.3 Remarks

There is no particular refinement of the steps of time to realize. There is 26 pas de time (release of a subdivision for not-convergence in 10 iterations), which corresponds to 110 iterations of Newton for complete calculation.

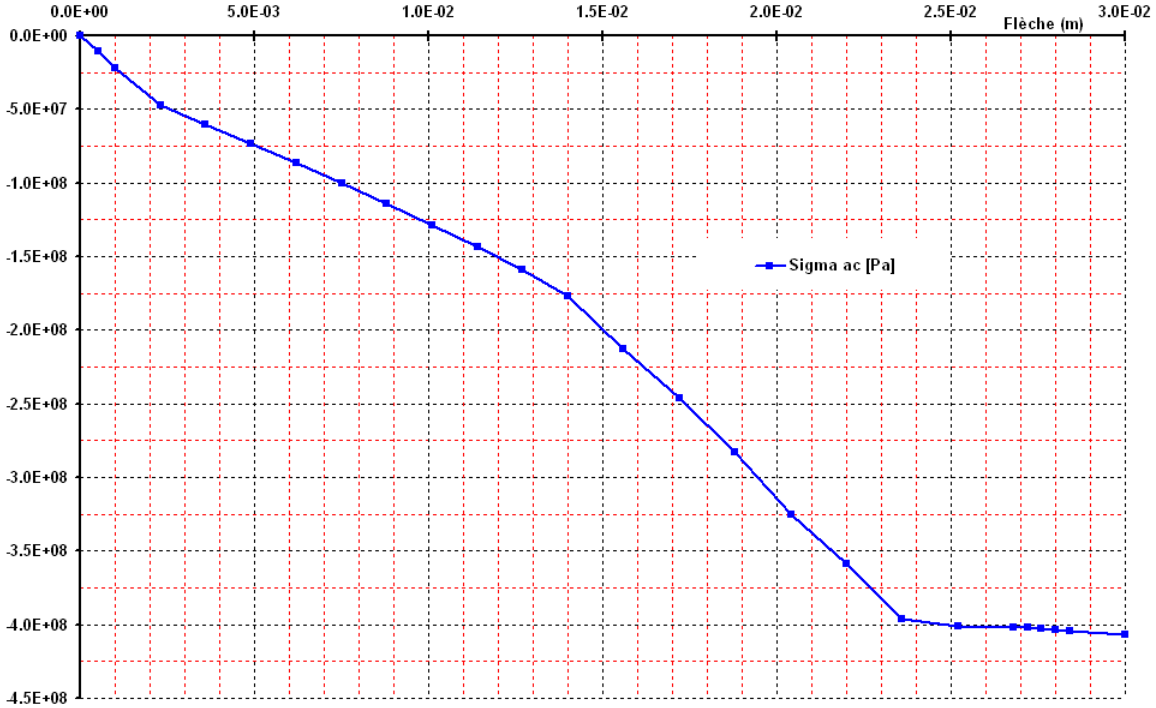

Figure 3.3-a : Contrainte compressed steel, according to the arrow in the center.

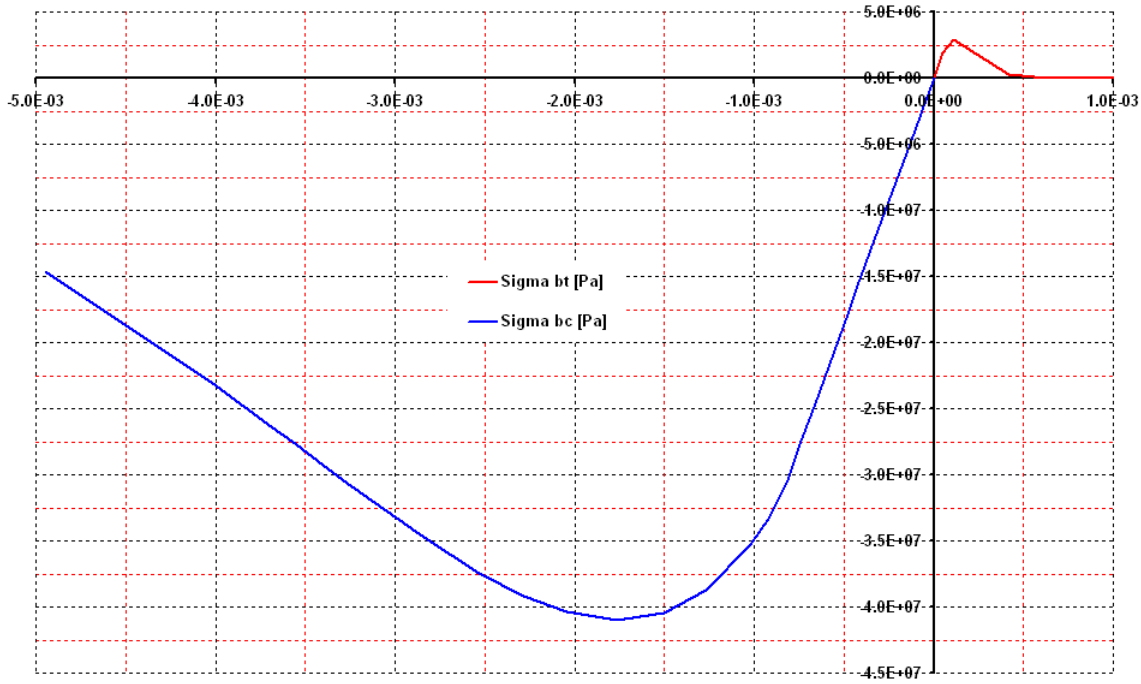

Figure 3.3-b : Comportement concrete.

4 Modeling B

4.1 Characteristics of modeling

The beam is modelled by elements DKTG and GRILLE_EXCENTRE. One uses 16 elements in the longitudinal direction X and only one in the transverse direction Z.

The reinforced concrete is modelled by the law of behavior GLRC_DM. Parameters of the law of behavior GLRC_DM are obtained thanks to the macro-order DEFI_GLRC. The data materials used are defined in 1.2. For the tablecloths of mainstays model GLRC, a section of reinforcement is defined $OMX=OMY=5,03\text{E-}4 m²/m$ and offsetting $RX=RY=0,872$.
One adds a grid of lower reinforcement with a section of $S=7,54E-4 m²/m$ and a offsetting of $-0,218 m$.

4.2 Sizes tested and results

The values result from experimental results (SOURCE_EXTERNE). The arrow is that of the center of the beam, the local results (deformations) are those of the point of Gauss of an element of the grid of reinforcement (nearest to the medium of the beam).
The law GLRC_DM being a homogenized reinforced concrete law, the constraints and deformations of the concrete or reinforcements included in the law are not accessible.

Reaction of support on center of edge a:

Arrow (m)	Size	Place	Standard reference	Reference	Tolerance
3,00E-03	REAC_NODA	DY group: With	SOURCE_EXTERNE	2,95780E+04	0.11
0.50E-02	REAC_NODA	DY group: With	SOURCE_EXTERNE	4,02560E+04	0.16
0.7E-02	REAC_NODA	DY group: With	SOURCE_EXTERNE	4,98640E+04	0.19
1.1E-02	REAC_NODA	DY group: With	SOURCE_EXTERNE	6,97240E+04	0,23
1.6E-02	REAC_NODA	DY group: With	SOURCE_EXTERNE	8,95840E+04	0,21
1.9E-02	REAC_NODA	DY group: With	SOURCE_EXTERNE	9,9940E+04	0,2
5.0E-02	REAC_NODA	DY group: With	SOURCE_EXTERNE	1.1768E+05	0.06

Arrow (m)	Size	Place	Standard reference	Tolerance
3,00E-03	REAC_NODA	DY group: With	NON_REGRESSION	1.0E-6
0.50E-02	REAC_NODA	DY group: With	NON_REGRESSION	1.0E-6
0.7E-02	REAC_NODA	DY group: With	NON_REGRESSION	1.0E-6
1.1E-02	REAC_NODA	DY group: With	NON_REGRESSION	1.0E-6
1.6E-02	REAC_NODA	DY group: With	NON_REGRESSION	1.0E-6
1.9E-02	REAC_NODA	DY group: With	NON_REGRESSION	1.0E-6
5.0E-02	REAC_NODA	DY group: With	NON_REGRESSION	1.0E-6

Deformation in tended steels:

Arrow (m)	Size	Place	Standard reference	Reference	Tolerance
3,00E-03	EXX	mesh: HM52, not: 1	SOURCE_EXTERNE	4.3175E-04	0,18
0.50E-02	EXX	mesh: HM52, not: 1	SOURCE_EXTERNE	4.1754E-04	0,34
0.7E-02	EXX	mesh: HM52, not: 1	SOURCE_EXTERNE	8.3099E-04	0,1
1.1E-02	EXX	mesh: HM52, not: 1	SOURCE_EXTERNE	1.2757E-03	0,13
1.6E-02	EXX	mesh: HM52, not: 1	SOURCE_EXTERNE	2.0344E-03	0,23
1.9E-02	EXX	mesh: HM52, not: 1	SOURCE_EXTERNE	2.5815E-03	0,29
5.0E-02	EXX	mesh: HM52, not: 1	SOURCE_EXTERNE	2.1200E-02	0,7

Arrow (m)	Size	Place	Standard reference	Tolerance
3,00E-03	EXX	mesh: HM52, not: 1	NON_REGRESSION	1.0E-6
0.50E-02	EXX	mesh: HM52, not: 1	NON_REGRESSION	1.0E-6
0.7E-02	EXX	mesh: HM52, not: 1	NON_REGRESSION	1.0E-6
1.1E-02	EXX	mesh: HM52, not: 1	NON_REGRESSION	1.0E-6
1.6E-02	EXX	mesh: HM52, not: 1	NON_REGRESSION	1.0E-6
1.9E-02	EXX	mesh: HM52, not: 1	NON_REGRESSION	1.0E-6
5.0E-02	EXX	mesh: HM52, not: 1	NON_REGRESSION	1.0E-6

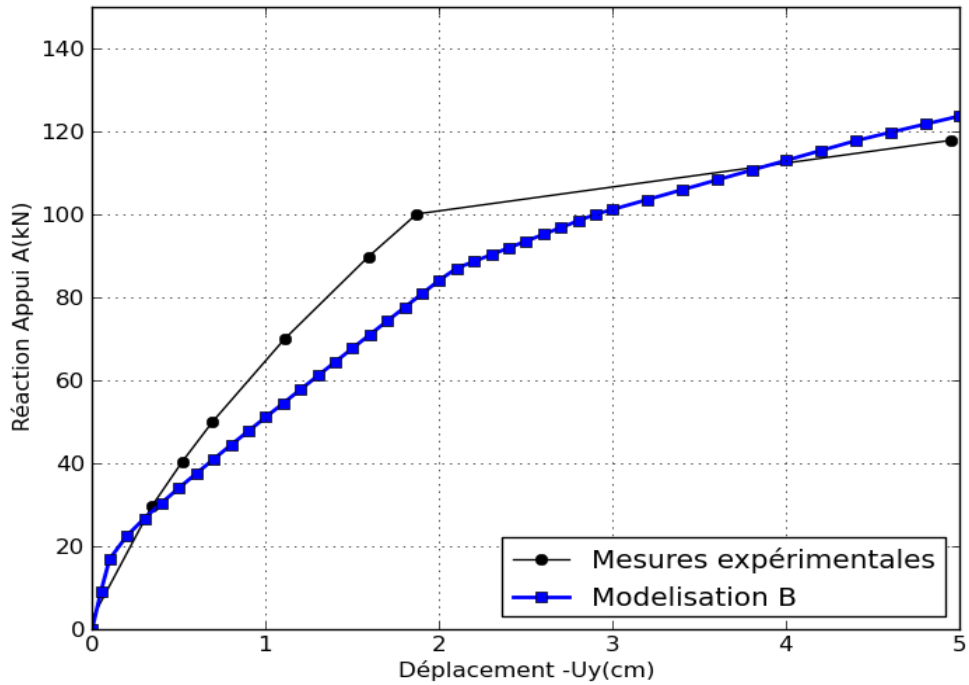

Figure 4.2-a : reaction on a support, according to the arrow in the center.

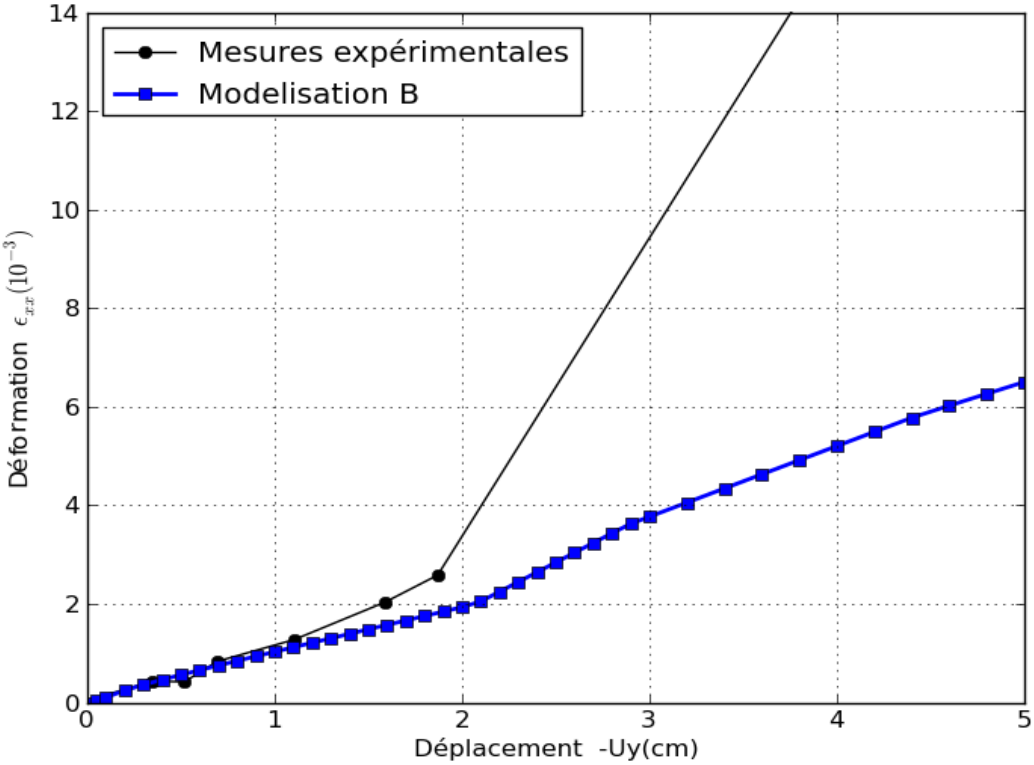

Figure 4.2-b : deformation of tended steels, according to the arrow in the center.

5 Modeling C

5.1 Characteristics of modeling

The beam is modelled by elements DKTG. One uses 16 elements in the longitudinal direction X and only one in the transverse direction Z .

The reinforced concrete is modelled by the law of behavior GLRC_DM. Parameters of the law of behavior GLRC_DM are obtained thanks to the macro-order DEFI_GLRC. The data materials used are defined in 1.2. For the tablecloths of mainstays model GLRC, a section of reinforcement is defined $OMX = OMY = 4{,}27\text{E-}3\ m^2/m$ and offsetting $RX = RY = 0{,}872$.

5.2 Sizes tested and results

The values result from experimental results (SOURCE_EXTERNE). The arrow is that of the center of the beam, the local results (deformations) are those of the point of Gauss of an element of the grid of reinforcement (nearest to the medium of the beam).
The law GLRC_DM being a homogenized reinforced concrete law, the constraints and deformations of the concrete or reinforcements included in the law are not accessible.

Reaction of support on center of edge a:

Arrow (m)	Size	Place	Standard reference	Reference	Tolerance
3,00E-03	REAC_NODA	DY group: With	SOURCE_EXTERNE	2,95780E+04	0,05
0.50E-02	REAC_NODA	DY group: With	SOURCE_EXTERNE	4,02560E+04	0,04
0.7E-02	REAC_NODA	DY group: With	SOURCE_EXTERNE	4,98640E+04	0,06
1.1E-02	REAC_NODA	DY group: With	SOURCE_EXTERNE	6,97240E+04	0,06
1.6E-02	REAC_NODA	DY group: With	SOURCE_EXTERNE	8,95840E+04	0,11
1.9E-02	REAC_NODA	DY group: With	SOURCE_EXTERNE	9,9940E+04	0,15
5.0E-02	REAC_NODA	DY group: With	SOURCE_EXTERNE	1.1768E+05	1,32

Arrow (m)	Size	Place	Standard reference	Tolerance
3,00E-03	REAC_NODA	DY group: With	NON_REGRESSION	1.0E-6
0.50E-02	REAC_NODA	DY group: With	NON_REGRESSION	1.0E-6
0.7E-02	REAC_NODA	DY group: With	NON_REGRESSION	1.0E-6
1.1E-02	REAC_NODA	DY group: With	NON_REGRESSION	1.0E-6
1.6E-02	REAC_NODA	DY group: With	NON_REGRESSION	1.0E-6
1.9E-02	REAC_NODA	DY group: With	NON_REGRESSION	1.0E-6
5.0E-02	REAC_NODA	DY group: With	NON_REGRESSION	1.0E-6

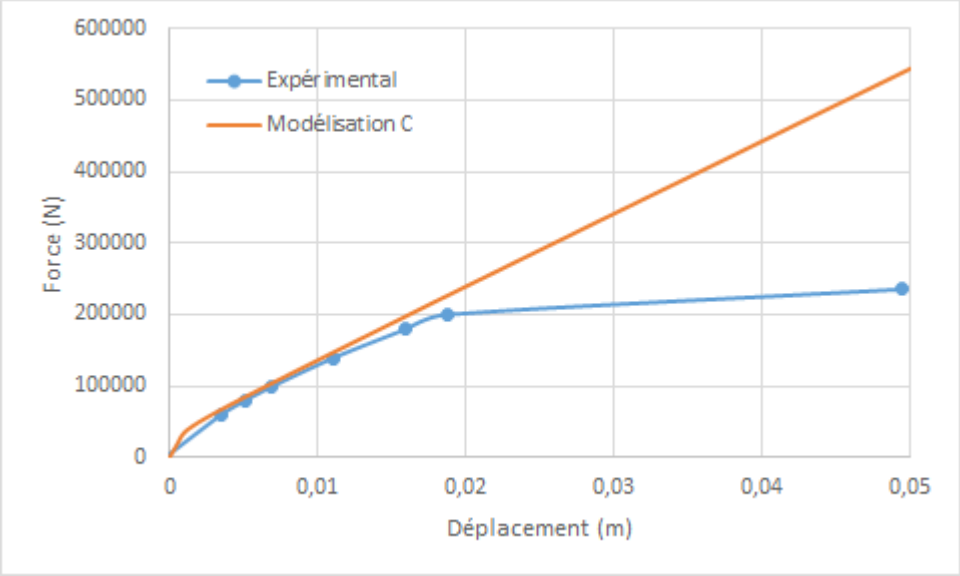

Figure 5.2-a : Reaction of support according to the arrow in the center

6 Modeling D

6.1 Characteristics of modeling

The beam is modelled by elements DKTG. One uses 16 elements in the longitudinal direction X and only one in the transverse direction Y .

The reinforced concrete is modelled by the law of behavior DHRC. The parameters of the law are obtained thanks to the plugin of eponymous identification in Salomé-Meca. The data materials used are defined in 1.2.

6.2 Sizes tested and results

The values result from experimental results (SOURCE_EXTERNE). The arrow is that of the center of the beam.

Reaction of support on center of edge a:

Arrow (m)	Size	Place	Standard reference	Reference	Tolerance
3,00E-03	REAC_NODA	DY group: With	SOURCE_EXTERNE	2,95780E+04	0.7
0.50E-02	REAC_NODA	DY group: With	SOURCE_EXTERNE	4,02560E+04	0.7
0.7E-02	REAC_NODA	DY group: With	SOURCE_EXTERNE	4,98640E+04	0.7
1.1E-02	REAC_NODA	DY group: With	SOURCE_EXTERNE	6,97240E+04	0.7
1.6E-02	REAC_NODA	DY group: With	SOURCE_EXTERNE	8,95840E+04	0.7
1.9E-02	REAC_NODA	DY group: With	SOURCE_EXTERNE	9,9940E+04	0.75
5.0E-02	REAC_NODA	DY group: With	SOURCE_EXTERNE	1.1768E+05	2.2

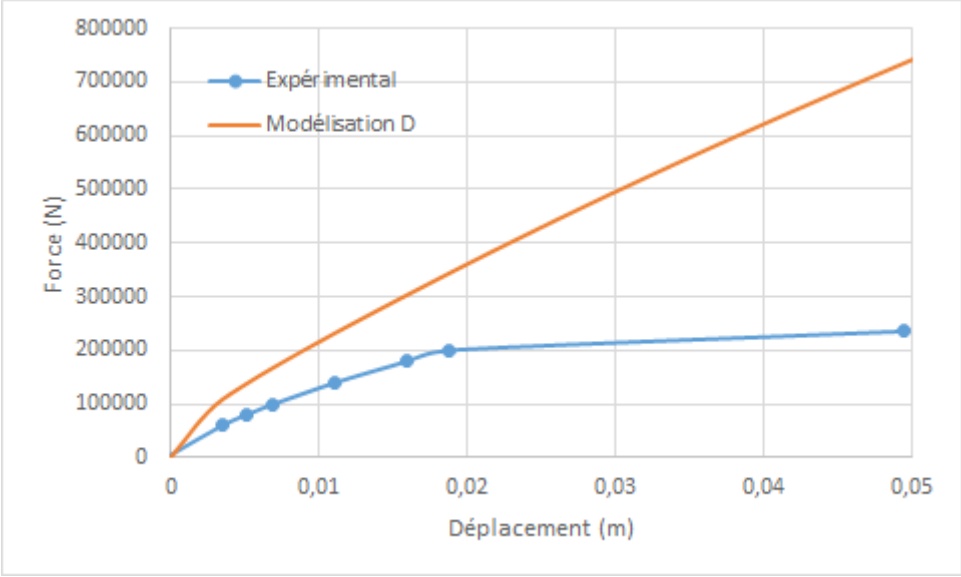

Figure 6.2-a : Reaction of support according to the arrow in the center

7 Summary of the results

The tests are carried out in not-regression owing to the fact that there does not exist reference with the law of behavior of Mazars or GLRC_DM. The coefficients of the law of Mazars are fixed in order to stick as well as possible to a curve of concrete behavior obtained with the law of Borderie (which is not available any more in *Code_Aster*).

For modelings of B with D, the results are also compared with experimental measurements.