SDNL130 - Seismic response of a reinforced concrete beam (rectangular section) to nonlinear behavior

Summary:

The problem consists in analyzing the seismic answer of a reinforced concrete beam. Comportement of the beam BA is nonlinear. Two modelings are studied :

- the beam is represented by a modeling beam multifibrbe [R3.08.08]. The law of behavior of the concrete is Mazars in its version 1D [R7.01.08] for modeling A;
- the beam is represented by elements DKTG. The non-linear law of behavior used is GLRC_DM [R7.01.32] for modeling B.

1 General characteristics

1.1 Geometry

The geometry is identical to that of the CAS-tests SSNL119 and SDLL130 except for the longitudinal reinforcements which all are here identical: they are four $HA32$.

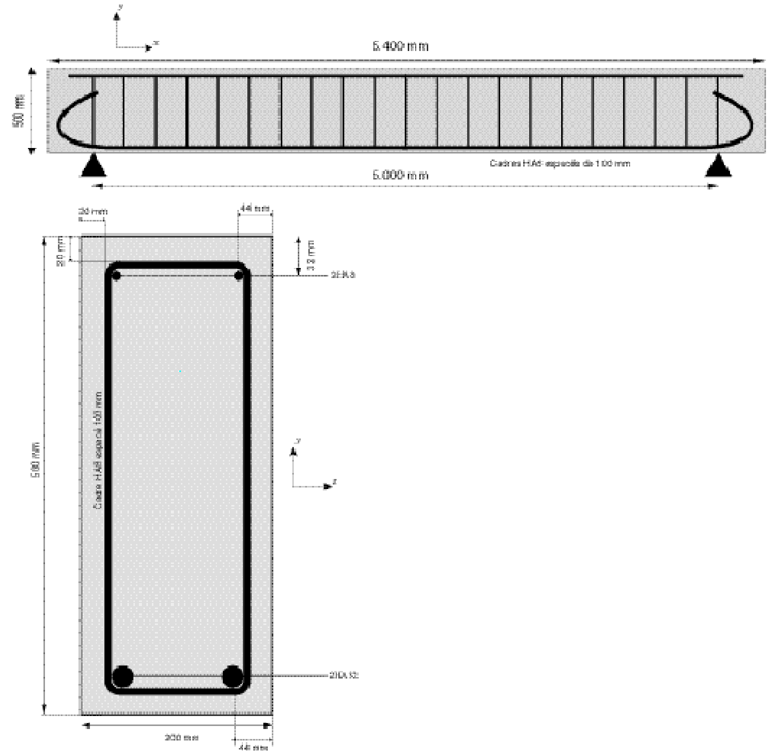

Figure 1.1-a : Geometry of the structure

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

1.2 Material properties

For modeling a:

For the concrete, law of behavior of Mazars in its version 1D:

Elasticity part:

$E=3.72720\text{E+}10$, $NU=2.0\text{E-}01$, $RHO=2.40\text{E+}03$,

Non-linear part:

$AC=1.71202987$, $BC=2.01163780\text{E+}03$, $BT=1.21892353\text{E+}04$,
$BETA=1.10$, $AT=1.00$, $EPSD0=8.20396008\text{E-}05$,

For modeling b:

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: $\sigma_{fc}=38.3\,MPa$

For modelings A and b:

Law of behavior ECRO_LINE for steel:

$E=200\,000\,MPa$, $\nu=0.33$, $\sigma_e=400\,MPa$, $E_T=3\,280\,MPa$, $\rho=7800\,kg/m^3$

Damping: of Rayleigh type ($\alpha K+\beta M$), with 5% on modes 1 and 2.

1.3 Boundary conditions and loadings

Simple support in B : $dy=0$

Support "doubles" in A : $dx=dy=0$

To avoid the clean modes except plan, one blocks the following degrees of freedom on all the beam: $rx=ry=dz=0$

Loading: earthquake `ac_s2_c_1` [Figure 1.3-a], in the axis OY applied to the two supports, with a factor of amplification of the signal of 45.

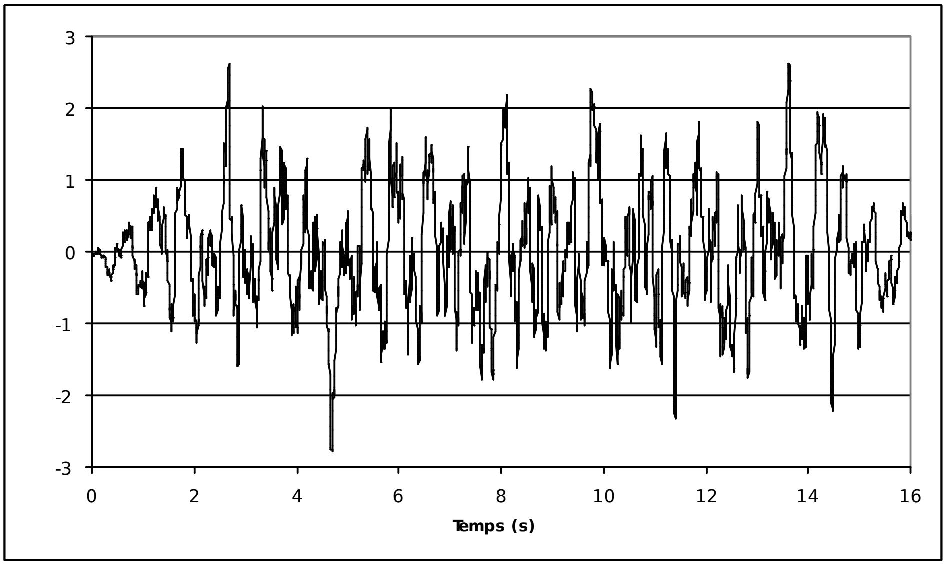

Figure 1.3-a : hasccélérogramme ac_s2_c_1 imposed on the structure

2 Reference solution

The tests carried out are only of standard not-regression.

3 Modeling A

3.1 Characteristics of modeling

Longitudinal grid of the beam:
It is composed of 17 nodes and 16 pairs of elements `POU_D_EM` (16 elements for the concrete and 16 for steel).

Cross section of the beam:
The concrete is modelled by a grid made up of 2×20 quadrilaterals (40 fibres).
Steel is modelled by 4 specific fibres.

Coefficients α and β for damping are calculated using the following formula:

$$\begin{bmatrix}\alpha\\\beta\end{bmatrix}=2\frac{\omega_1\omega_2}{\omega_2^2-\omega_1^2}\begin{bmatrix}\frac{-1}{\omega_2} & \frac{1}{\omega_1}\\\omega_2 & -\omega_1\end{bmatrix}\begin{bmatrix}\xi_1\\\xi_2\end{bmatrix}$$

where ω_1 and ω_2 are the first two own pulsations $(\omega=2\pi f)$ and ξ_1 and ξ_2 are the depreciation wished on the first two modes.

With $f_1=39.9\,Hz$ and $f_2=157.6\,Hz$ (calculated with *Code_Aster*), for modal depreciation of 5% , we find: $\alpha=8.10^{-5}$ and $\beta=20$.

The step of selected time is $0{,}01\,s$.
The law for the behavior of the concrete is Mazars in its version $1\mathrm{D}$.

3.2 Sizes tested and results

The curves of reaction of support according to time as well as the arrow in the center according to time are presented on the figures 3.2-a with 3.2-b.

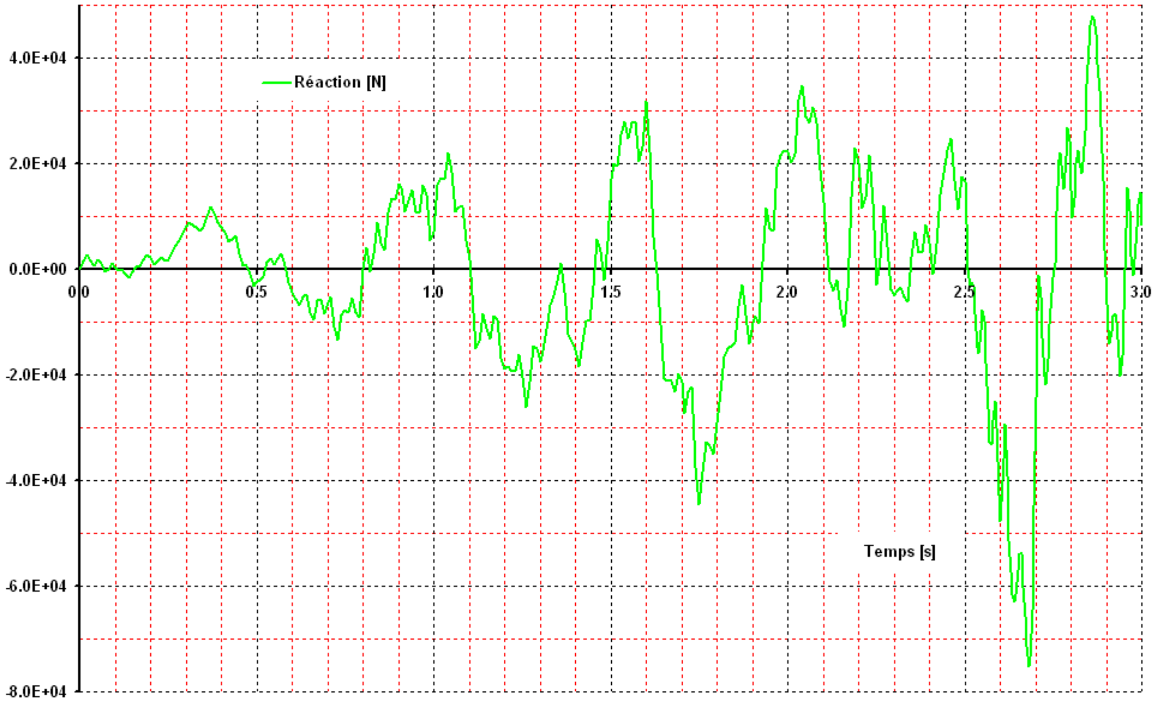

Figure 3.2-a : Réaction of support A according to time for the three first second.

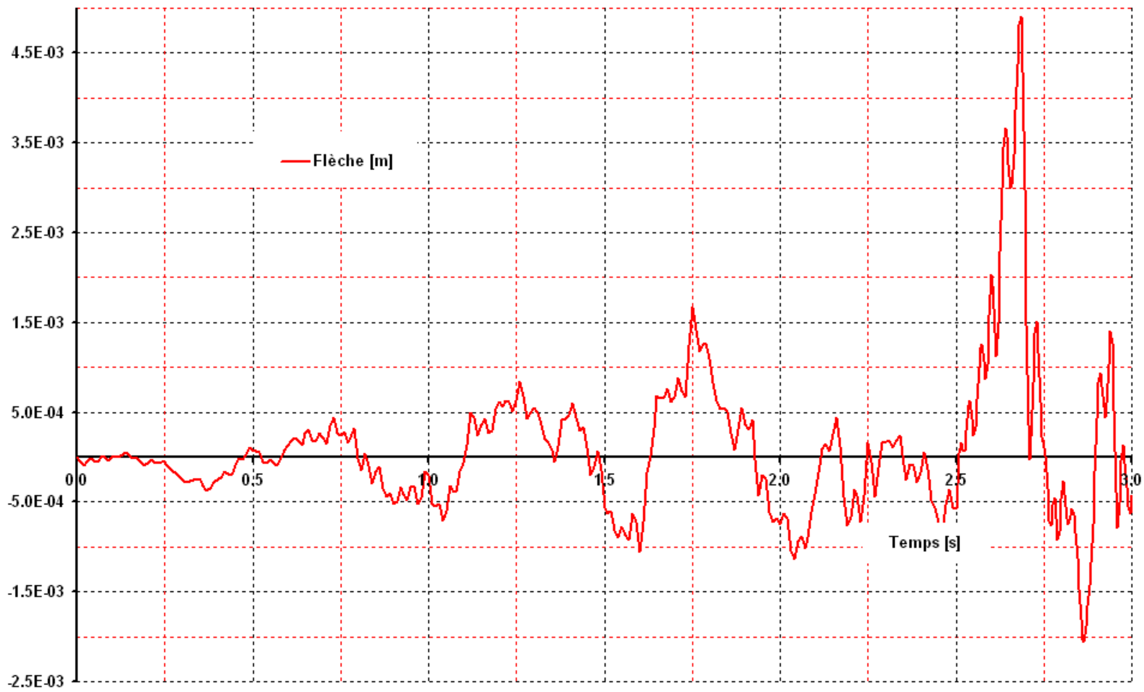

Figure 3.2-b : Flick in the center according to time for the three first second.

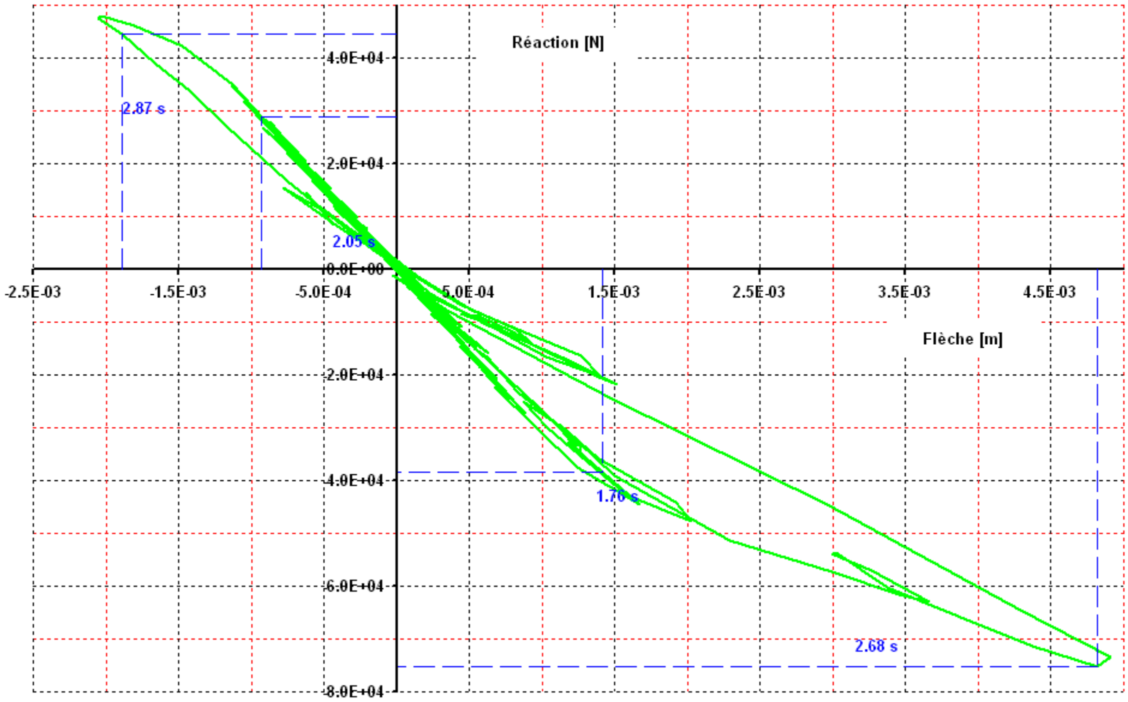

Figure 3.2-c : Courbe reaction-marks with arrows for the three first second.

The tests are carried out for the reaction on the first support and the arrow in the center. One tests these values for a few moments in the three first second of earthquake, i.e. at times $1.76s$ (any beginning of the nonlinear field), then $2.05s$, $2.68s$ and $2.87s$ when the structure is already strongly damaged.

Moment	Size	Place	Standard Reference	Tolerance
1.76 S	FORC_NODA: DY	group: With	NON_REGRESSION	1.0E-06
1.76 S	DEPL: DY	group: C	NON_REGRESSION	1.0E-06
2.05 S	FORC_NODA: DY	group: With	NON_REGRESSION	1.0E-06
2.05 S	DEPL: DY	group: C	NON_REGRESSION	1.0E-06
2.68 S	FORC_NODA: DY	group: With	NON_REGRESSION	1.0E-06
2.68 S	DEPL: DY	group: C	NON_REGRESSION	1.0E-06
2.87 S	FORC_NODA: DY	group: With	NON_REGRESSION	1.0E-06
2.87 S	DEPL: DY	group: C	NON_REGRESSION	1.0E-06

The figures below give the evolutions of the reaction on support A and the arrow to the center, for 15 seconds.

Figure 3.2-d : Réaction of support in A according to time, for 15 seconds.

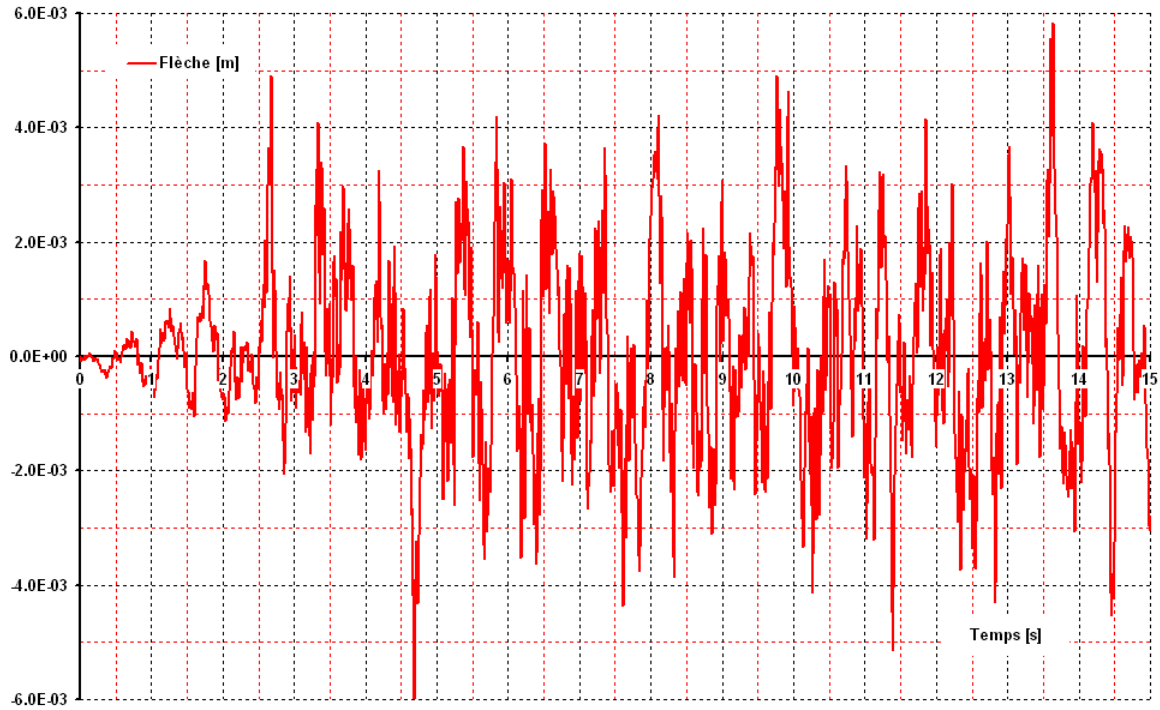

Figure 3.2-e : Flick in the center according to time, for 15 seconds.

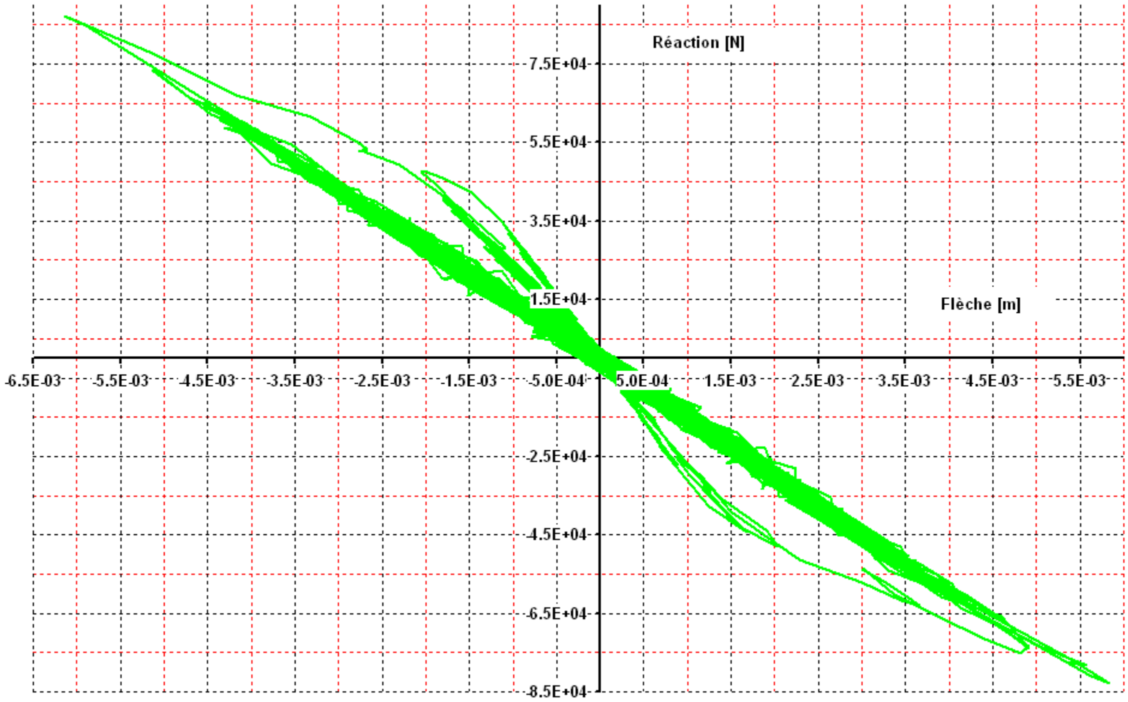

Figure 3.2-f : Courbe reaction-marks with arrows, for 15 seconds.

4 Modeling B

4.1 Characteristics of modeling

The beam is modelled by elements DKTG and GRILLE_EXCENTREE. 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 $OMX=OMY=8{,}04\text{E-}4\,m^2/m$ and offsetting $RX=RY=0{,}872$. The option is used SLOPE = ' PLAS_ACIER'.

The first two Eigen frequencies (calculated with *Code_Aster*) are $f_1=38.7\,Hz$ and $f_2=153.2\,Hz$. For modal depreciation of 5%, one obtains the damping coefficients $\alpha=8.10^{-5}$ and $\beta=20$. These coefficients are provided to the macro-order DEFI_GLRC.

4.2 Sizes tested and results

The curves of reaction according to time as well as the arrow in the center according to time are presented on the figures 4.2-a with 4.2-f.

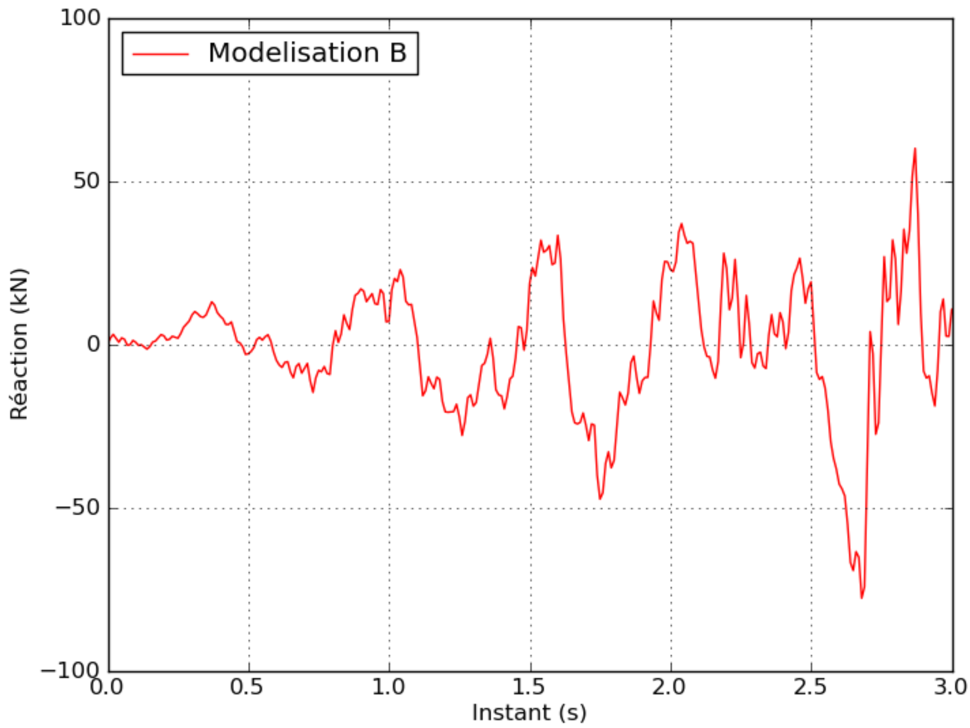

Figure 4.2-a : Réaction of support in A according to time for the three first second.

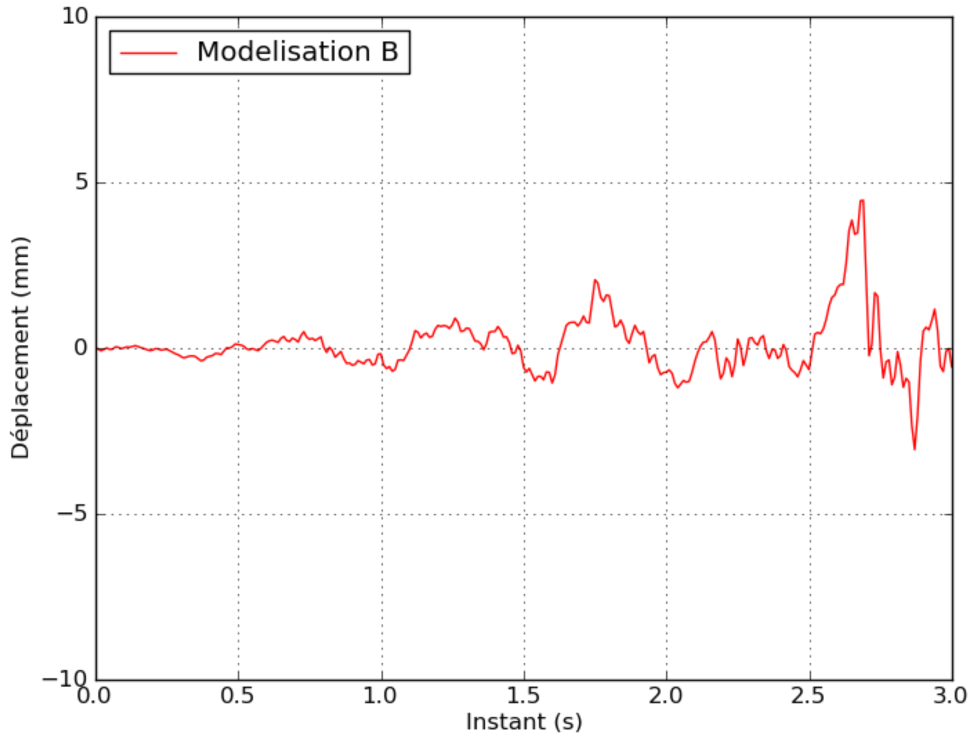

Figure 4.2-b : Flick in the center according to time for the three first second.

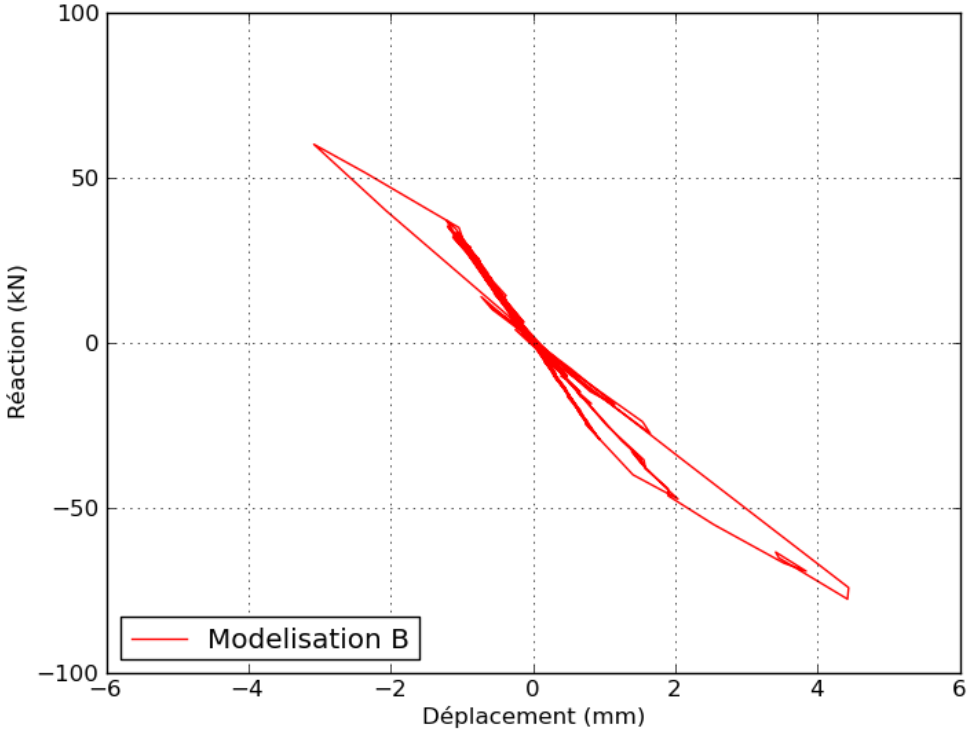

Figure 4.2-c : curve reaction-marks with arrows for the three first second.

The tests are carried out for the reaction on the first support and the arrow in the center. One tests these values for a few moments in the three first second of earthquake, i.e. at times $1.76s$ (any beginning of the nonlinear field), then $2.05s$, $2.68s$ and $2.87s$ when the structure is already strongly damaged.

Moment	Size	Place	Standard Reference	Tolerance
1.76 S	FORC_NODA: DY	group: AA	NON_REGRESSION	1.0E-06
1.76 S	DEPL: DY	group: DC	NON_REGRESSION	1.0E-06
2.05 S	FORC_NODA: DY	group: AA	NON_REGRESSION	1.0E-06
2.05 S	DEPL: DY	group: DC	NON_REGRESSION	1.0E-06
2.68 S	FORC_NODA: DY	group: AA	NON_REGRESSION	1.0E-06
2.68 S	DEPL: DY	group: DC	NON_REGRESSION	1.0E-06
2.87 S	FORC_NODA: DY	group: AA	NON_REGRESSION	1.0E-06
2.87 S	DEPL: DY	group: DC	NON_REGRESSION	1.0E-06

The figures below give the evolutions of the reaction on support A and the arrow to the center, for 15 seconds.

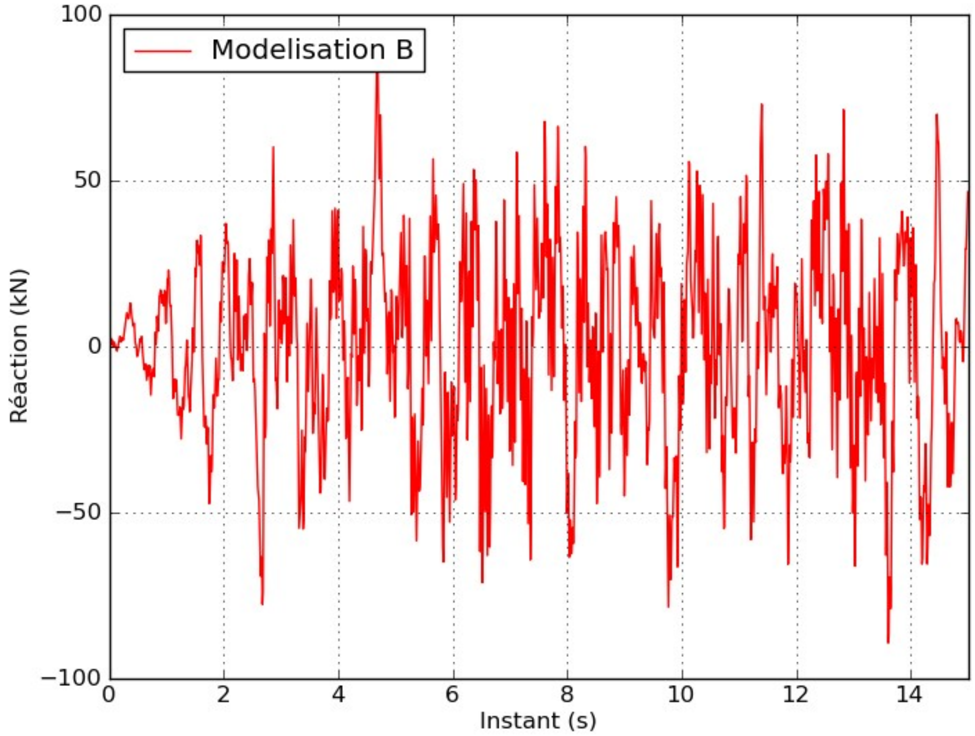

Figure 4.2-d : Réaction of support in A according to time, for 15 seconds.

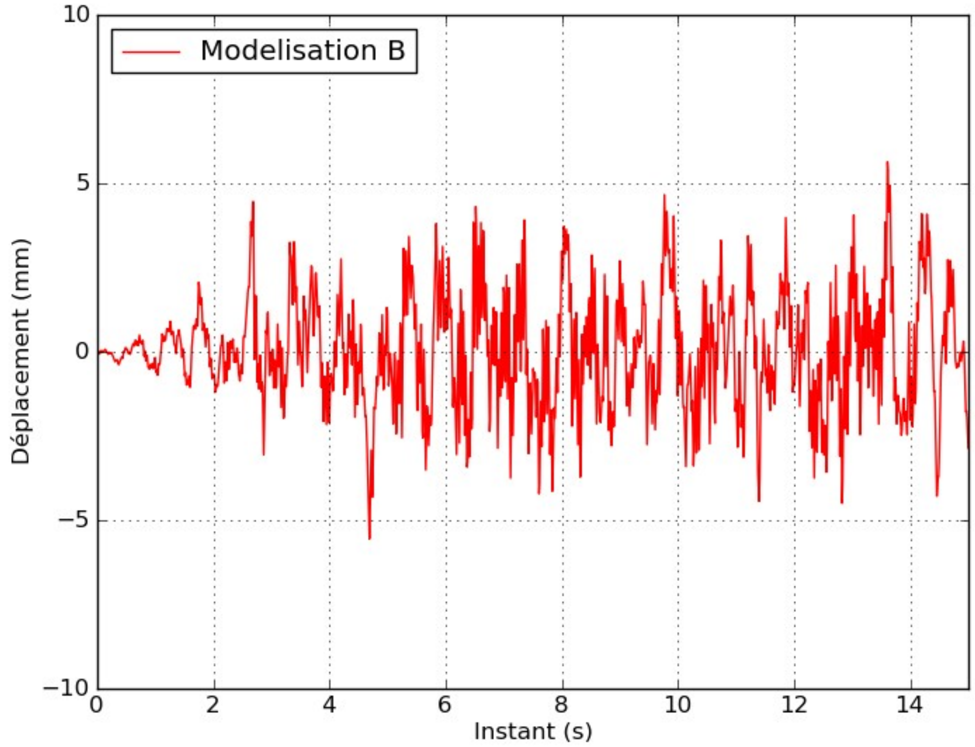

Figure 4.2-e : F lick in the center according to time, for 15 seconds.

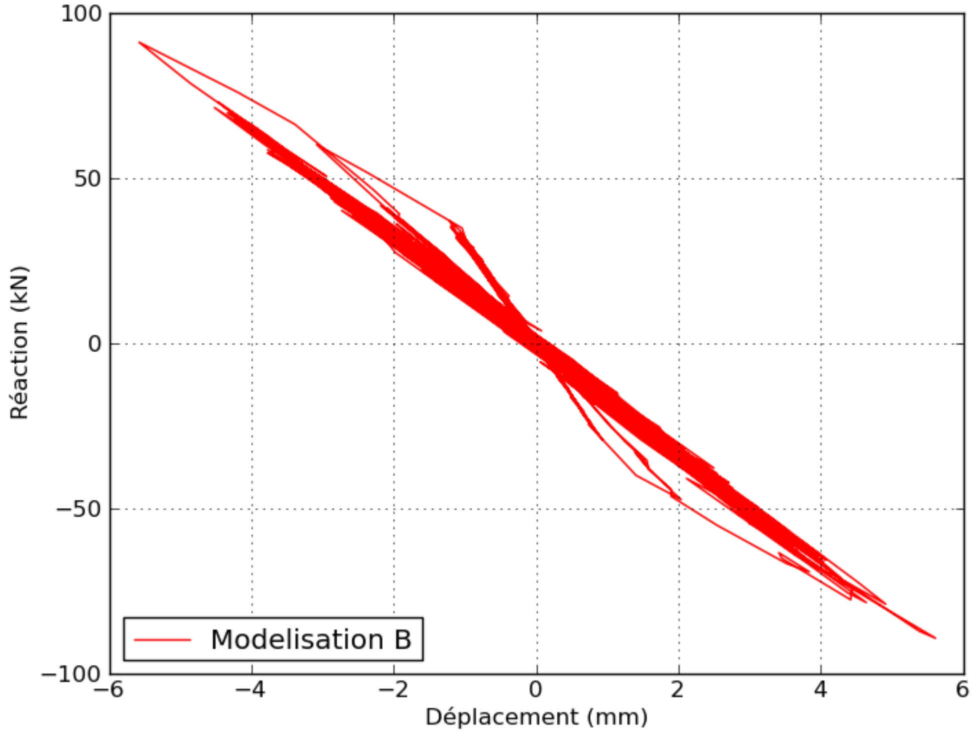

Figure 4.2-f : Courbe reaction-marks with arrows, for 15 seconds.

5 Summary of the results

Two modelings give similar results in terms of force and displacements.

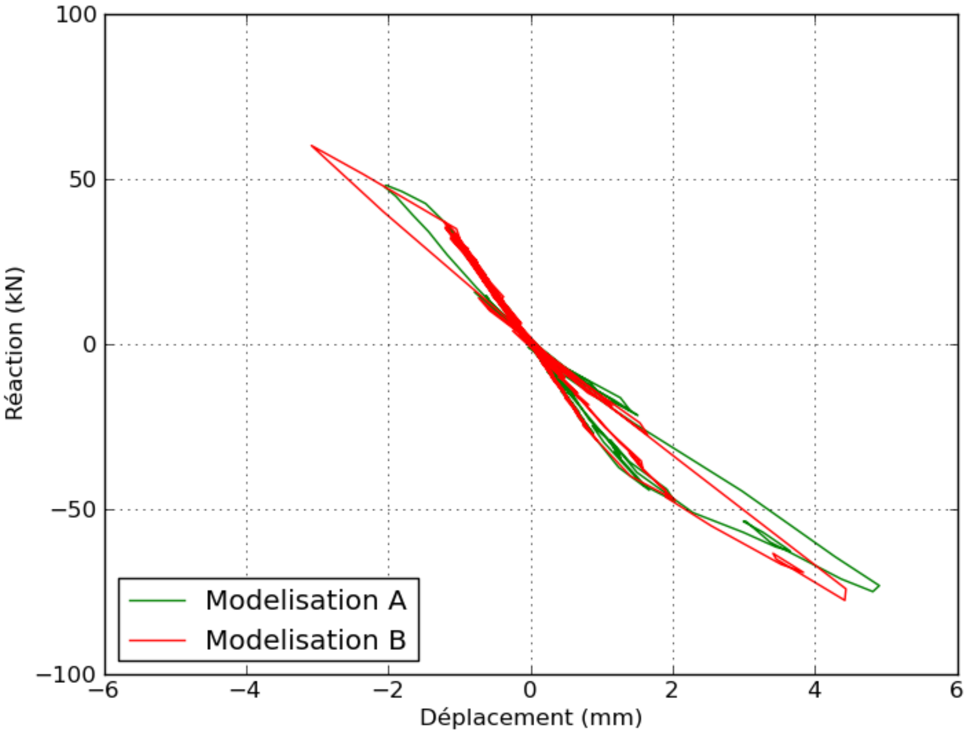

Figure 5-a: Courbe reaction-marks with arrows for three seconds.