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

Abstract:

The problem consists in a beam modelization analyzing the seismic response of a reinforced concrete beam via multifibre [R3.08.08]. The behavior of the beam BA is nonlinear. Two constitutive law for the concrete are used:

- Borderie in its version 1D [R7.01.07] for modelization A.
- Mazars in its version 1D [R7.01.08] for the modelization B.

1 Characteristic general

1.1 Geometry

the geometry is identical to that of the cases test `SSNL119` and `SAFE` SDLL130 for longitudinal reinforcements which are identical: 4 $HA32$

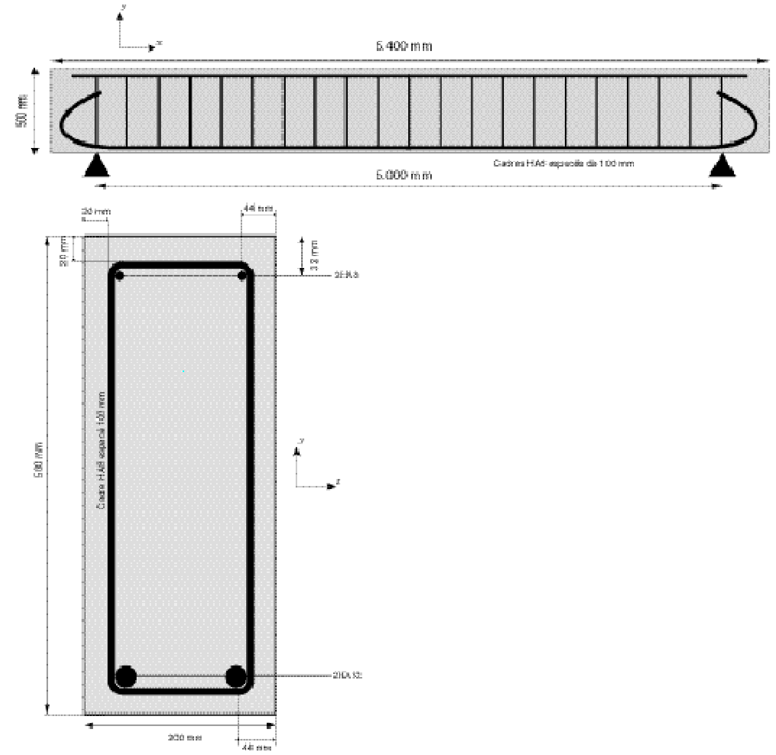


Figure Geometry of the structure

NB: transverse reinforcements are not taken into account in computations

1.2 Material properties

For modelization a:

For the concrete, constitutive law of Borderie in its version 1D:

$$E=37\,272\,MPa \quad \nu=0.2 \quad \sigma_{ft}=3.9\,MPa \quad \sigma_{fc}=38.3\,Mpa \quad \varepsilon_{fc}=2.0.10^{-3}$$
$$G_f^1=110\,J/m\,,\ \rho=2400\,kg/m^3$$

For modelization b:

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

Elasticity part:

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

Left nonlinear:

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

For the modelizations A and b:

Constitutive law `ECRO_LINE` for steel:

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

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

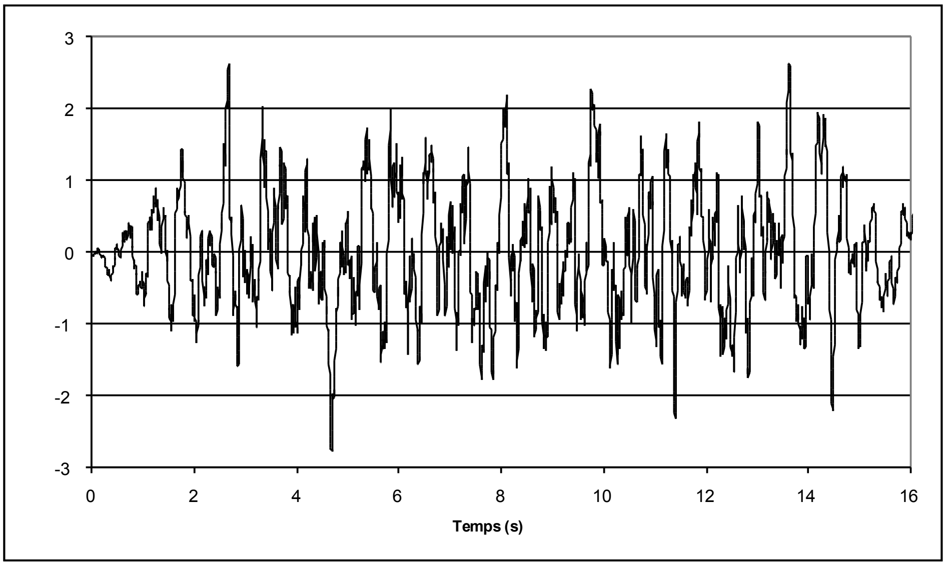
1.3 Boundary conditions and loadings

simple Bearing in B : $dy=0$

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

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

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



Appear 1.3-aAccelerogram ac_s2_c_1 imposed on the structure

2 Reference solution

the reference solution is a computation carried out using the computer code EFICOS [bib1]. It is about a computation multi-layer (2D) with the same models for the materials. The elements comprise only one Gauss point according to their axis and the total resolution is made by an algorithm with secant matrix.

To have comparable results in terms of localization and terms of results local (stresses and strains at the Gauss point nearest to the medium of the beam), computation with EFICOS (1 point by element) is carried out with 10 elements per half bay whereas computation with *Code_Aster* (2 points per element) is carried out with 8 elements per half bay.

This difference in integration is the main source of the differences noted in the paragraph [§4].

2.1 Bibliographical references

[name 1] 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.

3 Modelization A

3.1 Characteristic of the modelization

longitudinal Mesh of 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 beam:
The concrete is modelled by a mesh (DEFI_GEOM_FIBRE/SECT) composed of 2×20 quadrilaterals (40 fibers)

steel is modelled by 4 specific fibers (DEFI_GEOM_FIBRE/ FIBER)

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

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

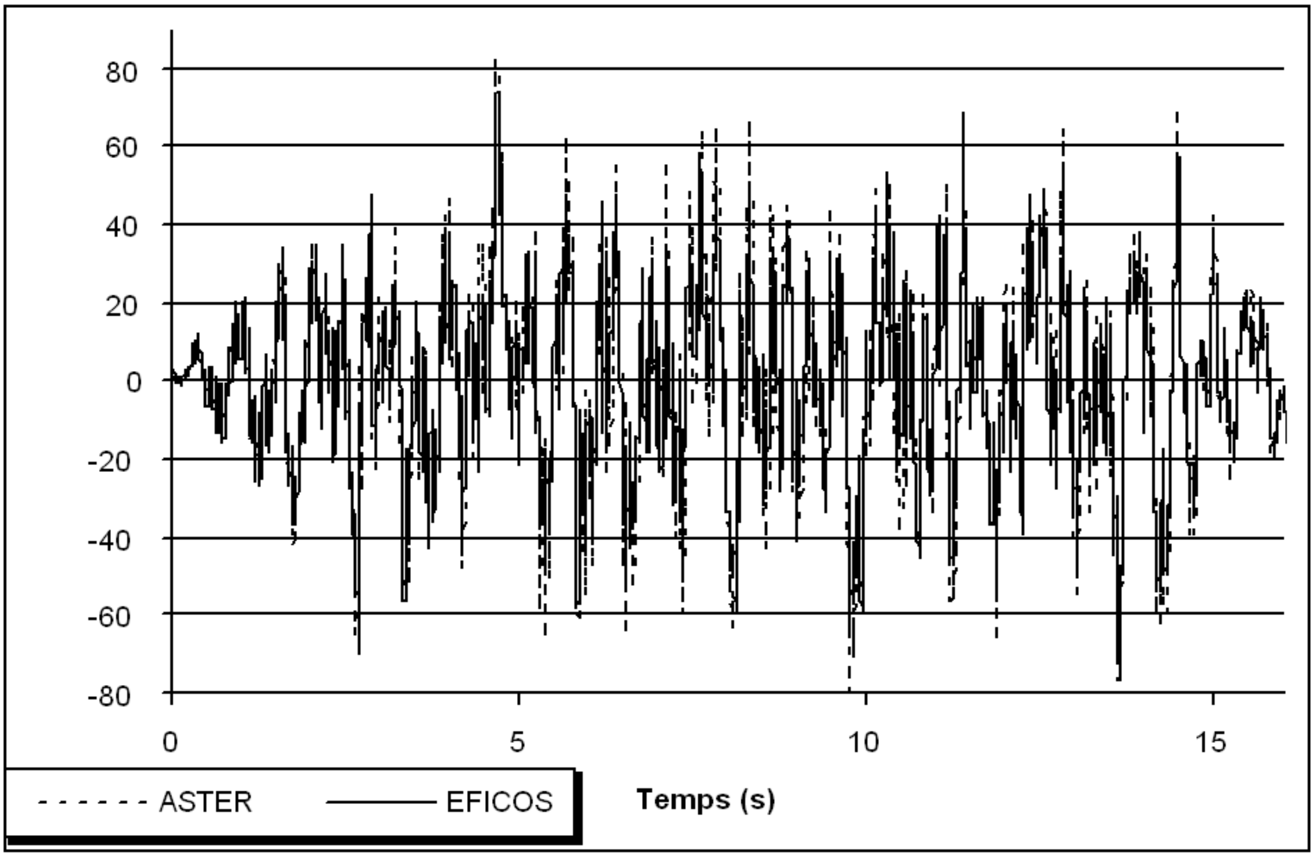
where ω_1 etsont ω_2 the first two own pulsations $(\omega=2\pi f)$ and ξ_1 ξ_2 are the depreciation wished on the first two modes.

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

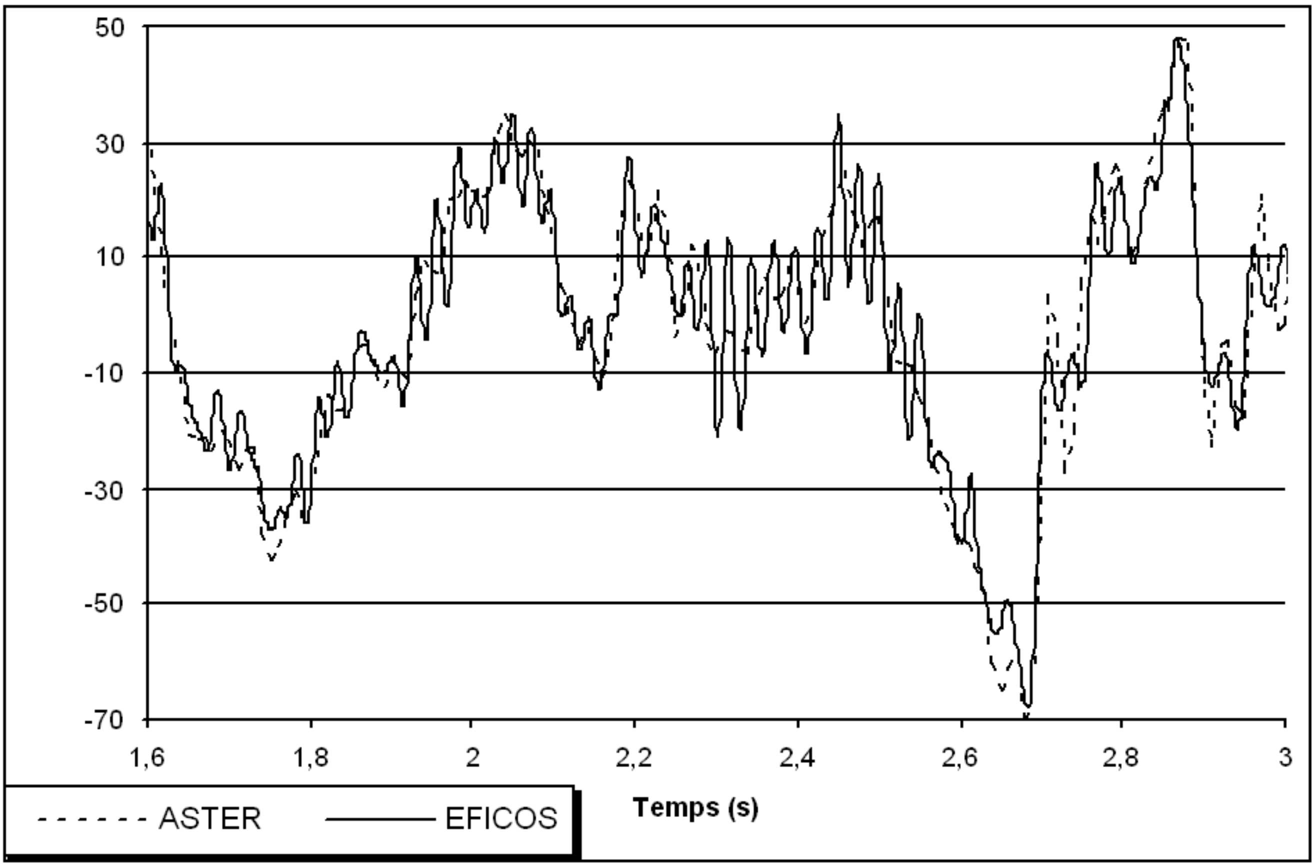
For the computation of the temporal response, the time step selected one is 1/100ème of second.

3.2 Quantities tested and results

the curves of reaction according to time and deflection in the center according to time are presented on the figures [Figure 3.2-a] with [Figure 3.2-d].



Appear Reaction to the first bearing according to time



Appears 3.2-bDetail of the reaction between 1,6 and 3 second

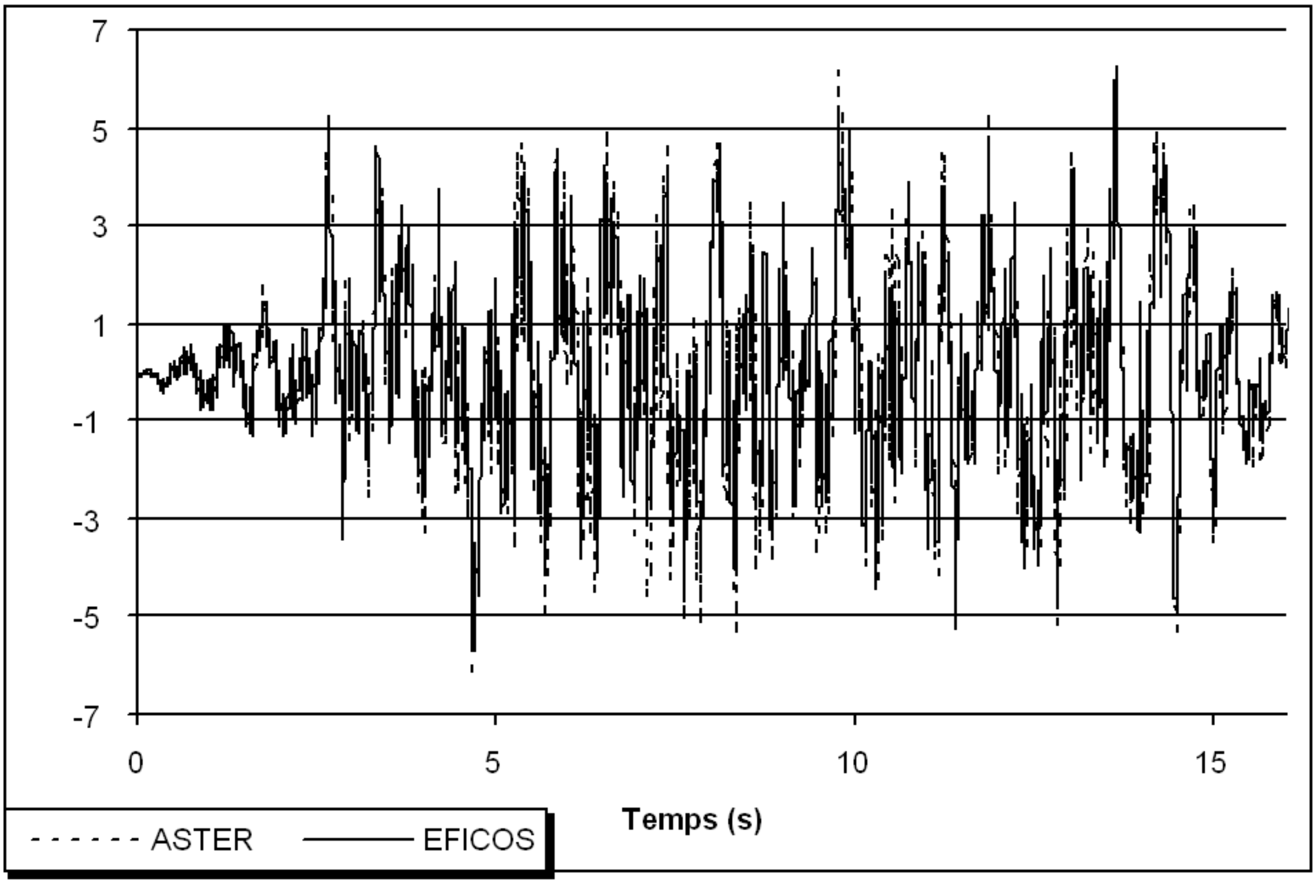
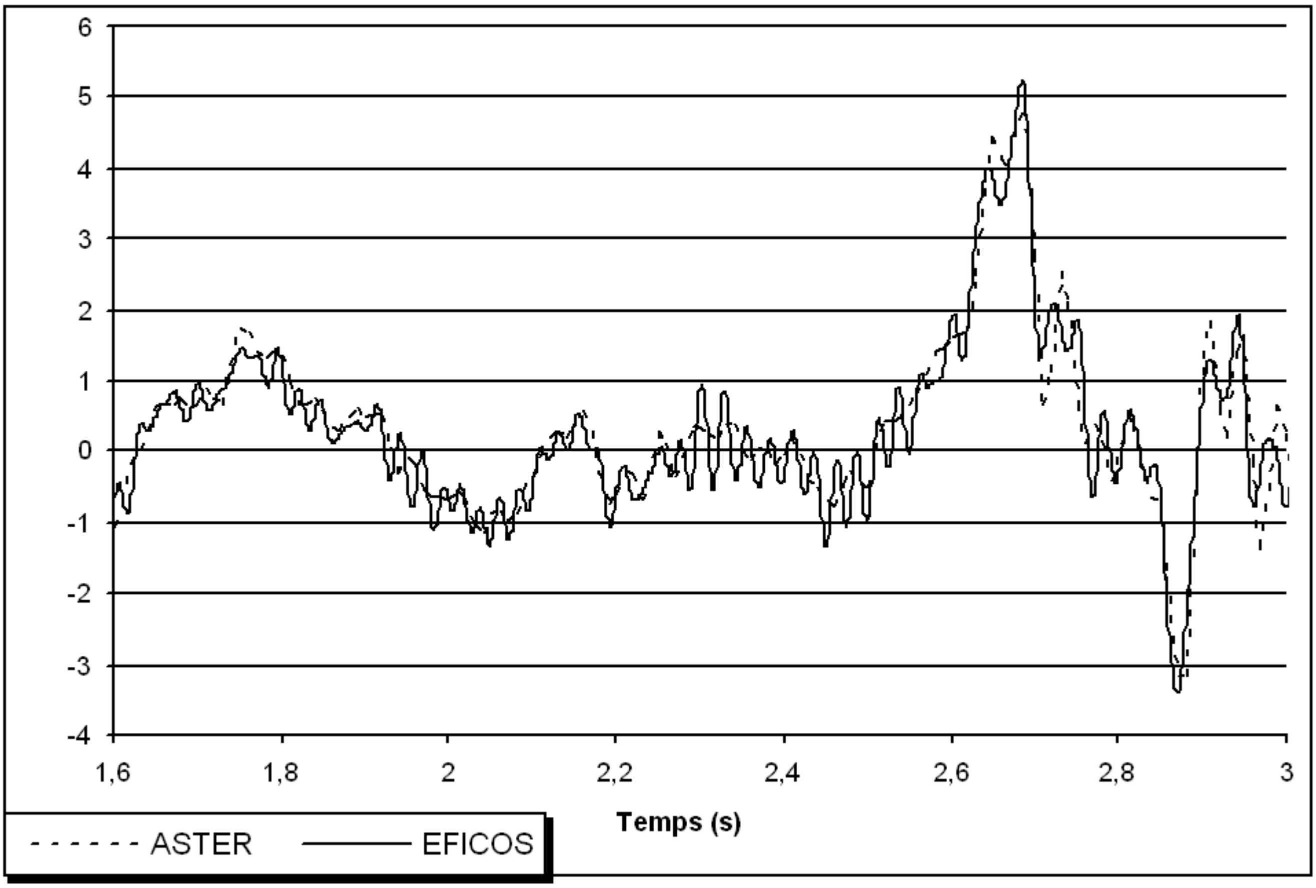
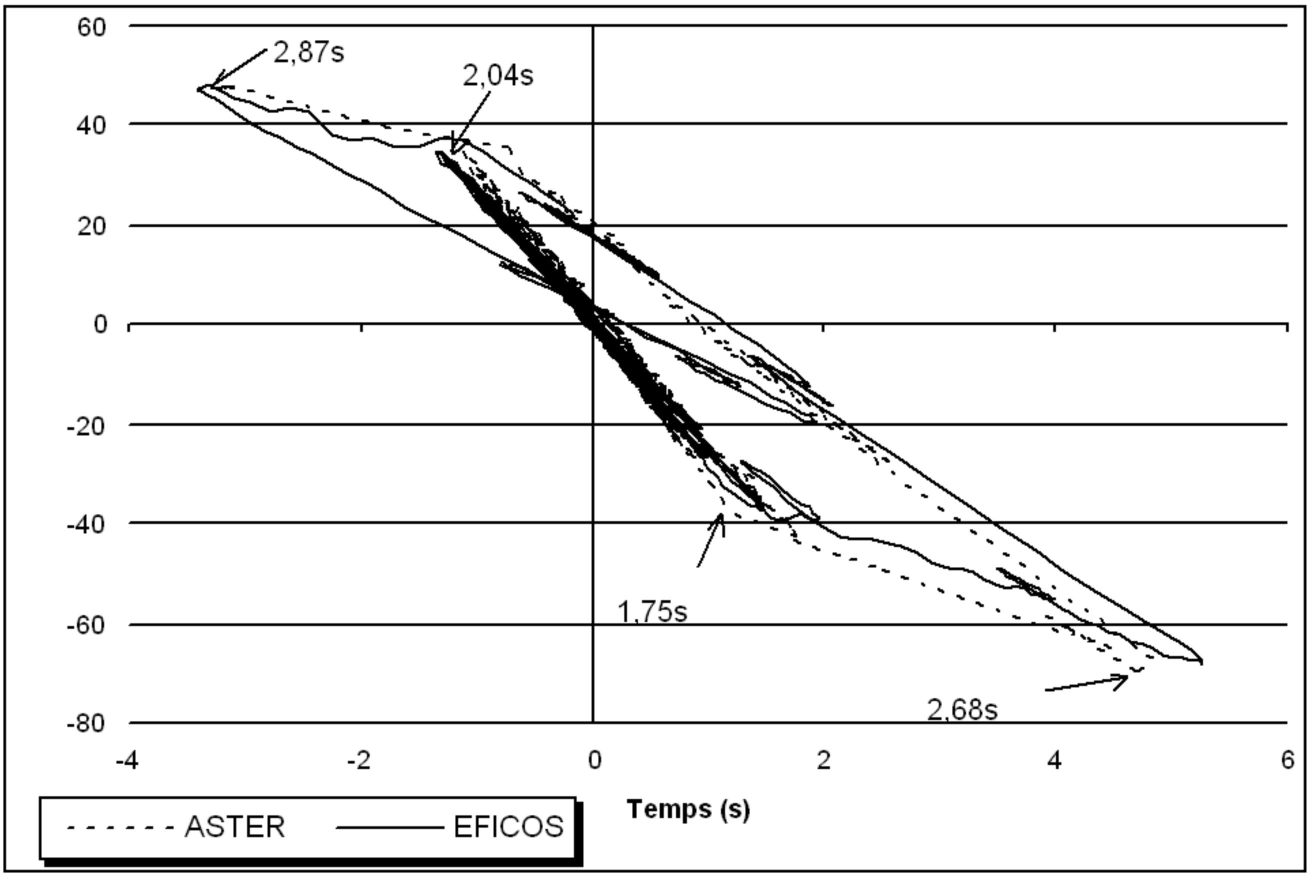


Figure Marks with arrows in the center according to time



Appears Detail of the deflection between 2,5 and 2,8 seconds

Note:
Solution EFICOS is more oscillating because the time step selected one with this code was 1/1000ème of second.



Appear 3.2-e : Curve reaction-deflection for the 3 first second

One of results carries out tests (`TEST_RESU`) for the reaction on the first bearing and the deflection in the center. One tests these values for some extremums in the 3 first second of seisme, i.e. in the neighborhoods as of time $1{,}75\,s$ (any beginning of the nonlinear field), then $2{,}04\,s$, $2{,}68\,s$ and $2{,}87\,s$ when the structure is already strongly damaged.

Note:
To have a case test which does not spend unnecessarily TEMPS CPU, only the 3 first second of seisme are tested.

DEFLECTION	EFICOS	ASTER	relative Error %
1.75 S	1.5E-03	1.7 E-03	13.3
2.04 S	– 1.3E-03	– 1.1E-03	13.1
2.68 S	5.2 E - 0 3.4.7	E-03	9.6
2.87 S	– 3.4E-03	– 3.1E-03	7.9

REACTION	EFICOS	ASTER	relative Error %
1.75 S	– 3.7E+04	– 4.2E+04	14.3
2.00 S	3.5E+04	3.5E+04	0.3
2.69 S	– 6.8E+05	– 6.7E+05	1.7
2.87 S	4.8E+05	4.8E+05	0.2

One notes that the differences in force in the nonlinear field are very weak, whereas there is an unquestionable difference for displacements. This difference is doubtless due to the effects of the damping which plays a great part on displacements.

4 Modelization B

4.1 Characteristic of the modelization

Identical to the modelization A, except:

- the model for the behavior of the concrete is Mazars in its version 1D .
- during computation with KEY DYNA_NON_LINE key NEWTON the matrix with the behavior is the tangent, with a reactualization with each iteration.

4.2 Quantities tested and results

the curves of reaction according to time and deflection in the center according to time are presented on the figures 4.2-a to 4.2-c .

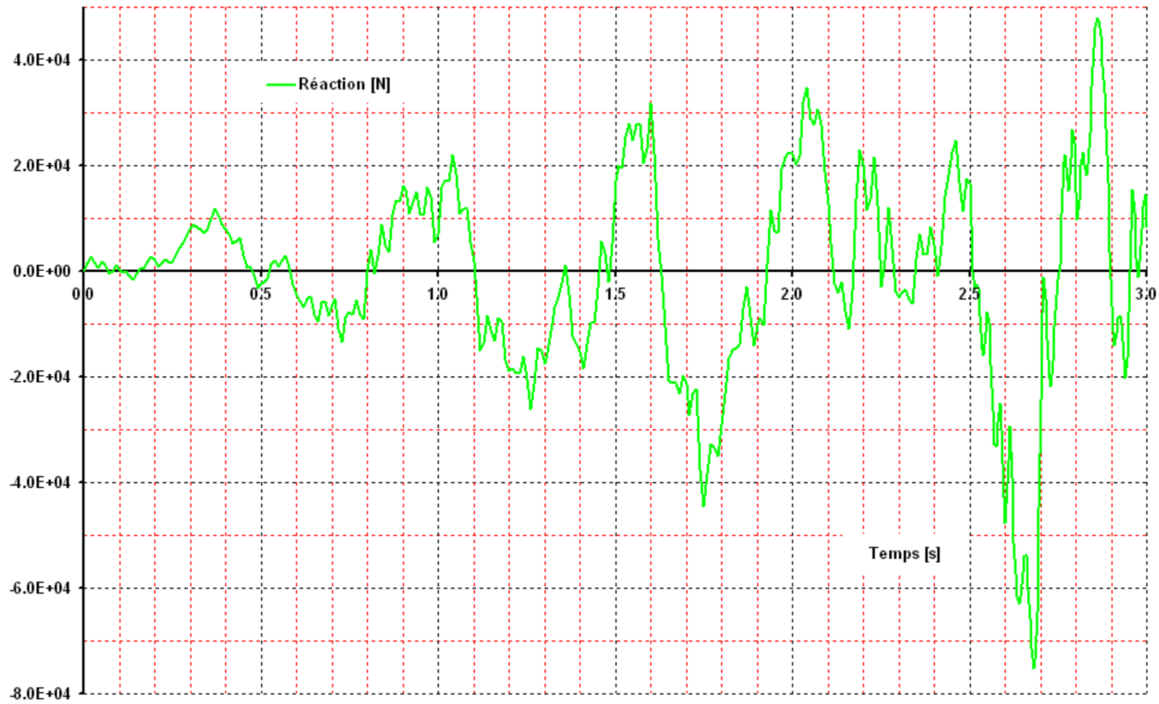
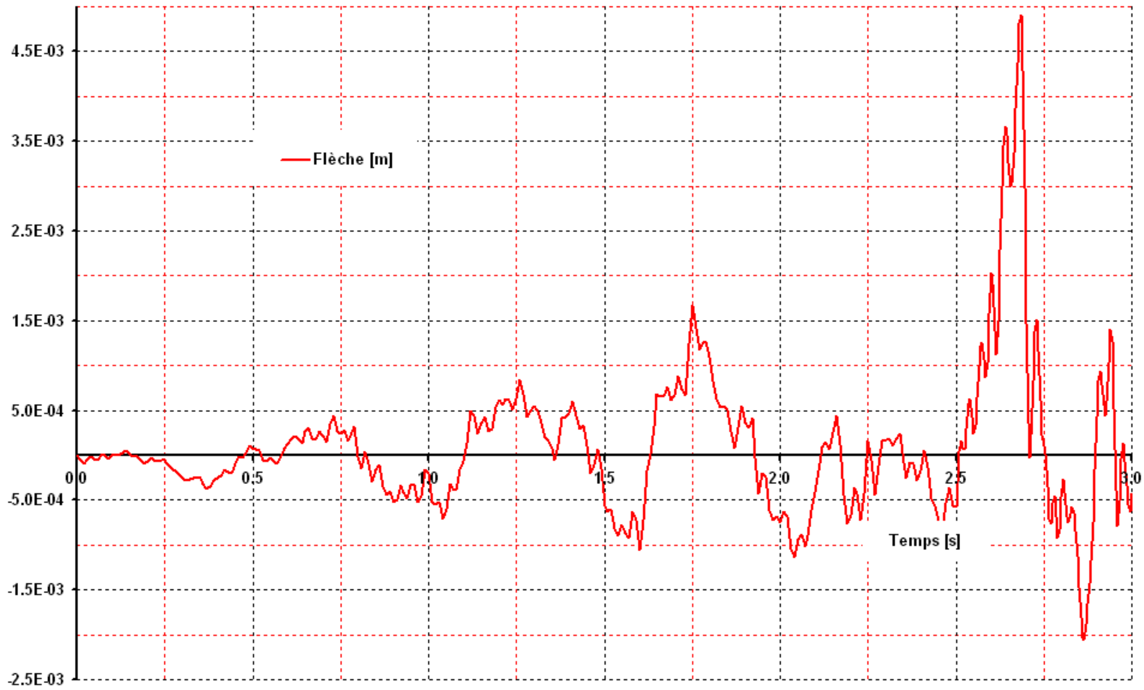
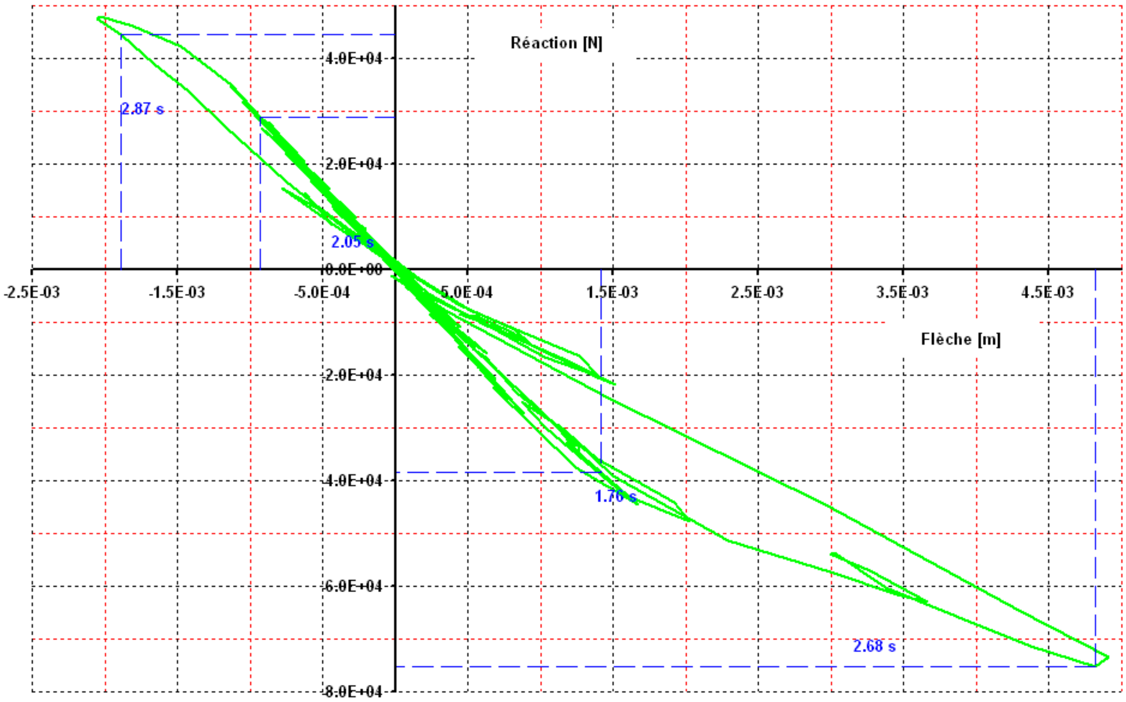


Figure 4.2-a : 4.2-a Reaction bearings A according to time, for the 3 first second.



Appear Marks with arrows in the center according to time, for the 3 first second.



Appear : Curve reaction-deflection for the 3 first second.

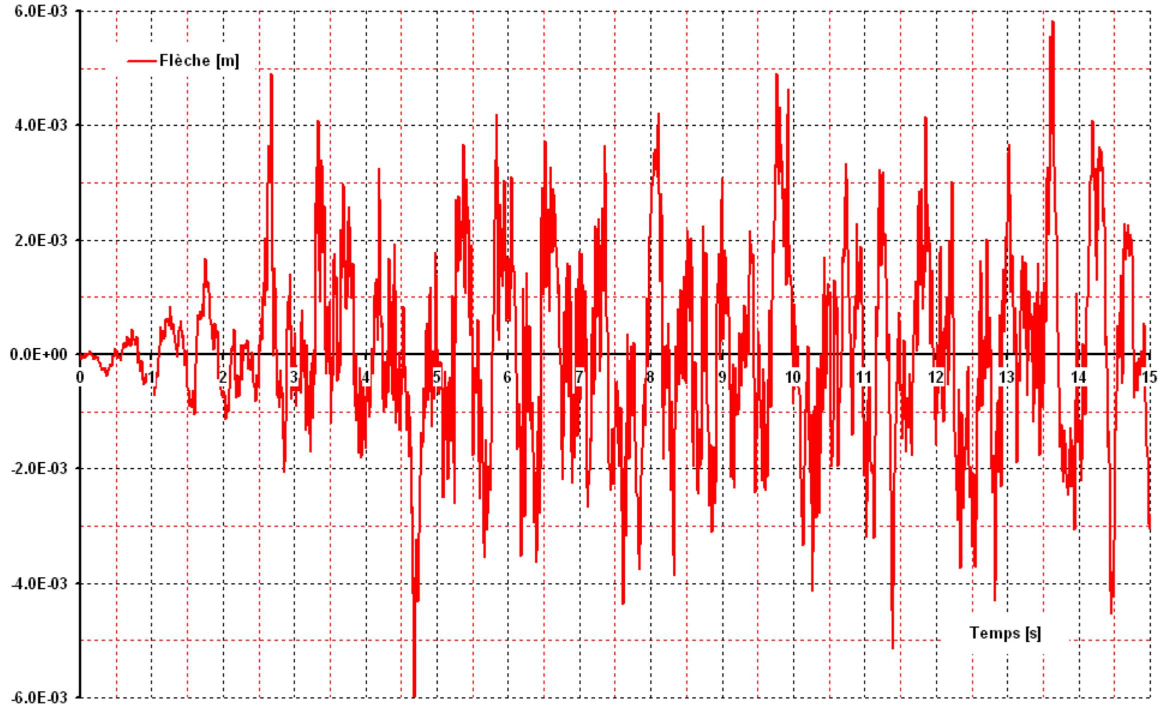
One of results carries out tests (`TEST_RESU`) for the reaction on the first bearing and the deflection in the center. One tests these values for a few time in the 3 first second of seisme, i.e. at times 1.76s (any beginning of the nonlinear field), then 2.05s, 2.68s and 2.87s when the structure is already strongly damaged.

Notice S :
In the case of the model of Mazars, it does not exist of reference, TEST_RESU are thus the non regression ones.

Time	Standard	Quantity	Place Reference	Référeces	Tolerance
1.76 S	FORC_NODA: DY	group: A	NON_REGRESSION	-3.8516E+04	1.0E-06
1.76 S	DEPL: DY	group: C	NON_REGRESSION	1.4170E-03	1.0E-06
2.05 S	FORC_NODA: DY	group: A	NON_REGRESSION	2.8814E+04	1.0E-06
2.05 S	DEPL: DY	group: C	NON_REGRESSION	-9.3312E-04	1.0E-06
2.68 S	FORC_NODA: DY	group: A	NON_REGRESSION	-7.5183E+04	1.0E-06
2.68 S	DEPL: DY	group: C	NON_REGRESSION	4.8174E-03	1.0E-06
2.87 S	FORC_NODA: DY	group: A	NON_REGRESSION	4.4564E+04	1.0E-06
2.87 S	DEPL: DY	group: C	NON_REGRESSION	-1.8913E-03	1.0E-06

the figures below A give the evolutions of the reaction on the bearing and the deflection to the center, for 15 seconds.

Appear : Reaction bearings A according to time, for 15 seconds.



Appear : Marks with arrows in the center according to time, for 15 second S.

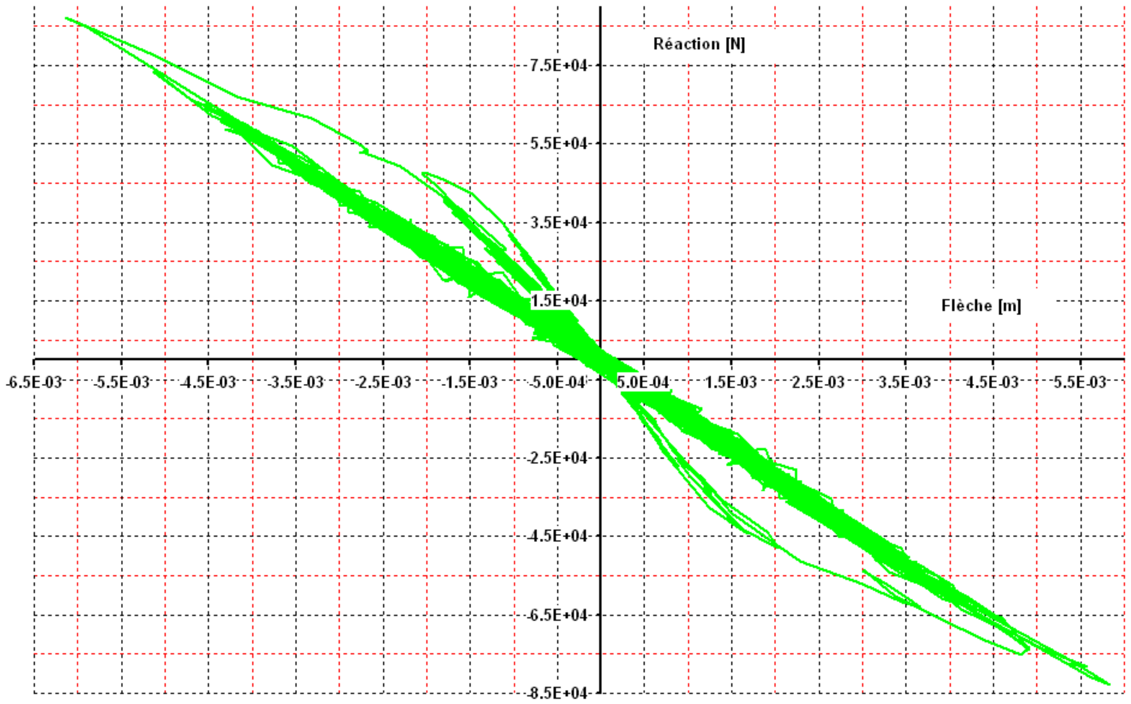


Figure Curve reaction-deflection, for 15 seconds.

5 Summary of the results

the results got with *Code_Aster* are in enough good agreement with those of code EFICOS.

The use of the model of Mazars (modelization B) makes it possible to strongly reduce the costs CPU (ratio higher than 3), for similar results.