PLEXU06 – Validation of the chaining *Code_Aster* - Europlexus

Summary:

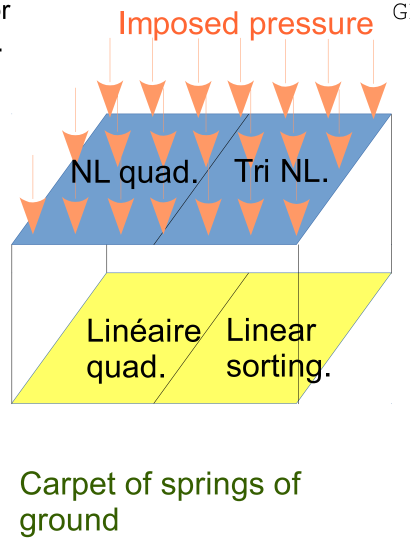
The purpose of this test is to validate the chaining of a non-linear transitory calculation where the first part of the resolution is carried out by Europlexus via the order CALC_EUROPLEXUS , then continues in *Code_Aster* with the use of the operator DYNA_NON_LINE, with a stage of rebalancing clarifies towards implicit carried out by the order MACRO_BASCULE_SCHEMA.
More precisely, the model implemented comprises following specificities:

- finite elements of standard beam (POU_D_ E),
- finite elements of type Q4GG on triangular or quadrangular meshs,
- carpet of springs of ground to model the ground under the foundation,
- loading of type variable pressure imposed in time,
- linear zone,
- non-linear zone with law of behavior GLRC_DAMAGE .

1 Description

1.1 General description

The structure is of standard square reinforced concrete gantry of $10\,m$ on side and $2\,m$ of top whose 4 posts are connected to their base with of an the same foundation raft cuts and resting on a carpet of springs of ground.
The foundation raft and the roof are represented in elements hulls of the type `Q4GG` . Only can be to you non-linear (law of behavior `GLRC_DAMAGE`) and it is subjected to a variable pressure in time.



The objective of this kind of study is to treat the fast dynamic part of the answer in Europlexus, for then rocking towards *Code_Aster* (into implicit) for the phase of induced shock, of which the duration in time is too large to allow a resolution in a reasonable time while remaining into explicit in Europlexus.

In postprocessing, one will analyze displacements, acceleration and the spectrum of answer of oscillator (SRO) at the point $PP2$ who is in the middle of the higher flagstone.

1.2 Properties of materials

The flagstones are out of reinforced concrete and the posts out of steel.

Material	Concrete	Steel
Young modulus	$E_b=42824{,}5\,MPa$	$E_a=2.10^{11}\,Pa$
Poisson's ratio	$\nu_b=0$	$\nu_a=0.3$
Density	$m_b=2500\,Kg/m^3$	$m_a=7800\,Kg/m^3$
`D_SIGM_EPSI`	0	0
`SY T`	$4{,}2.10^5\,MPa$	Without object
`SYC`	$-35.10^5\,MPa$	Without object
`SY`	Without object	$5.10^7\,MPa$

The linear part of the flagstones sees affected the linear characteristics of the concrete defined above.

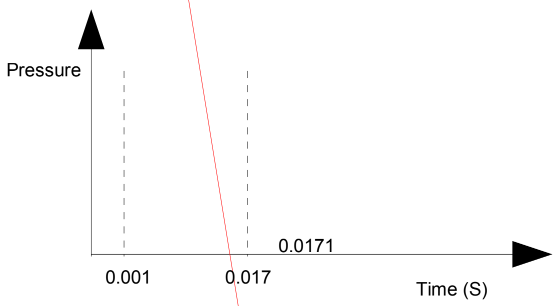
The complementary part is characterized by a behavior of the type GLRC_DAMAGE . , of which the phase concrete and the steel reinforcements have the characteristics above too.

Specific parameters of the law GLRC_DAMAGE are specified with the operator DEFI_GLRC .

CONCRETE		TABLECLOTH	
THICK	1.3	OMX	$5{,}027.10^{-3}$
GAMMA	0	OMY	$5{,}027.10^{-3}$
QP1	0.152	X-ray	0.877
QP2	0.152	RY	0.877
OMT	5.10^{-3}		
EAT	2.10^{11}		
C1N1 =C1N2=C1N3 =C2N1=C2N2=C2N3	$87{,}3.10^{6}$		
C 1M1 =C1M2=C1M3 =C2 MR. 1=C2M2=C2M3	$14{,}8.10^{6}$		

1.3 Boundary conditions and loading

The pressure imposed on the higher flagstone follows this pattern in time:



The foundation raft rests on a carpet of springs of ground (of type K_TR_D_N) defined with the keyword RIGI_PARASOL of AFFE_CARA_ELEM . The six components of the total stiffness as starter are worth:

$$Kx = 0{,}13572.10^{12}\,Pa$$
$$Ky = 0{,}13428.10^{12}\,Pa$$
$$Kz = 0{,}13467.10^{12}\,Pa$$
$$Krx = 0{,}24722.10^{15}\,Pa$$
$$Kry = 0{,}22386.10^{15}\,Pa$$
$$Krz = 0{,}30600.10^{15}\,Pa$$

1.4 Limitations imposed by time CPU

For reasons purely related to a time CPU runs for this CAS-test, one voluntarily will shorten the total duration which will be simulated numerically at the time of the transitory resolution. That also will induce a moment of rocker between the code which will be located too much “early”: the initial mode of fast dynamic response will not have been transformed into mode of overall shock. The cas-test will have thus the disadvantage to rock of diagram in time at one unfavourable moment where notlinearities will be still in phase of propagation, which should not be the case for a real industrial study where the phase of shock treated into implicit should remain linear.

Logically, the rocker should thus occur after the return to 0 of the imposed pressure (sufficient to be late in mode of shock), therefore afterwards $0{,}0171\,s$. Condition CFL imposing a step of time clarifies about $5\,\mu s$, the number of steps of time would be prohibitory for a CAS-test. In order to reduce time CPU, one much earlier places the rocker, towards $0{,}007\,s$, therefore when the imposed pressure is with its maximum plate. Into implicit the step of time will be of $50\,\mu s$.

1.5 Strategy of Europlexus passage towards *Code_Aster*

In this chapter one will approach two problems:
- the second reading and the construction of fields to pass from the Europlexus resolution (via CALC_EUROPLEXUS) with DYNA_NON_LINE : one will validate this stage by comparing calculations into explicit (one remains with diagram in similar time between the codes),
- the rocker of a diagram clarifies towards an implicit scheme.

1.5.1 Construction of the fields for the continuation

The model comprises a linear zone and a non-linear zone. On the linear zone, the fields which one will recover at the last moment calculated with Europlexus are the fields kinematics, therefore only fields with the nodes. The constraints will be recomputed in *Code_Aster*.

On the non-linear zone, it is necessary to read again two fields at the additional points of Gauss for the constraint and the internal variables related to the law materials employed: GLRC_DAMAGE . The non-linear zone comprises only elements of the type Q4GG on triangular or quadrangular meshs.

All the fields generated by Europlexus will be read again starting from a file MED.

For the continuation with DYNA_NON_LINE (or MACRO_BASCULE_SCHEMA) one defines as initial state the following fields: displacement, speed, acceleration, forced (on all the model) and internal variables.

1.5.2 Rock of diagram

One continues the transitory resolution, following Europlexus, in *Code_Aster* while starting by taking some steps with the diagram clarifies centered differences, with matrix of lumpée mass, so remaining on the same assumptions as Europlexus calculation. Then the transition towards an implicit resolution is done with a specific phase of rebalancing within the operator MACRO_BASCULE_SCHEMA . The transitory resolution thus finishes into implicit with matrix of consistent mass and for a step of time ten times larger than into explicit.

2 Reference solution

One will compare the results got with rocker of diagram with the got results when one preserves a single diagram in time. In order to quantify the differences between the codes, one will thus build two reference solutions: the first calculated with Europlexus, the second with *Code_Aster* into explicit.

2.1 Results of reference

One compared to reference solutions in terms of displacement, acceleration and SRO (for a damping coefficient of 5%) at the point $PP2$ who is in the middle of the higher flagstone. For the SRO, one also will compare the results got while making use of the tables ofOBSERVATION, in particular that generated by CALC_EUROPLEXUS with the data ofFILING.

2.2 Uncertainty on the solution

The ascribable variations with the rocker of diagram will be compared with the differences between the two reference solutions (one obtained with Europlexus, the other with *Code_Aster*). In the ideal, the rocker should little amplify these differences between the reference solutions, which them, cannot be reduced.

3 Modeling A

The concrete flagstones are modelled in elements Q4GG , on quadrangular or triangular meshs. The posts are modelled in elements of the type POU_D_E . The springs of ground are, as for them, of the type K_TR_D_N .

3.1 Analysis of the results

In this chapter, one will trace the vertical evolutions of the displacement and the acceleration of the point $PP2$ (in the middle of the higher flagstone). Each time, one will superimpose the various answers obtained:

1. resolution with CALC_EUROPLEXUS then continuation with DYNA_NON_LINE into explicit,
2. resolution with CALC_EUROPLEXUS on all the interval of study,
3. resolution with DYNA_NON_LINE clarify on all the interval of study,
4. rock CALC_EUROPLEXUS towards DYNA_NON_LINE implicit,
5. rock DYNA_NON_LINE clarify towards implicit.

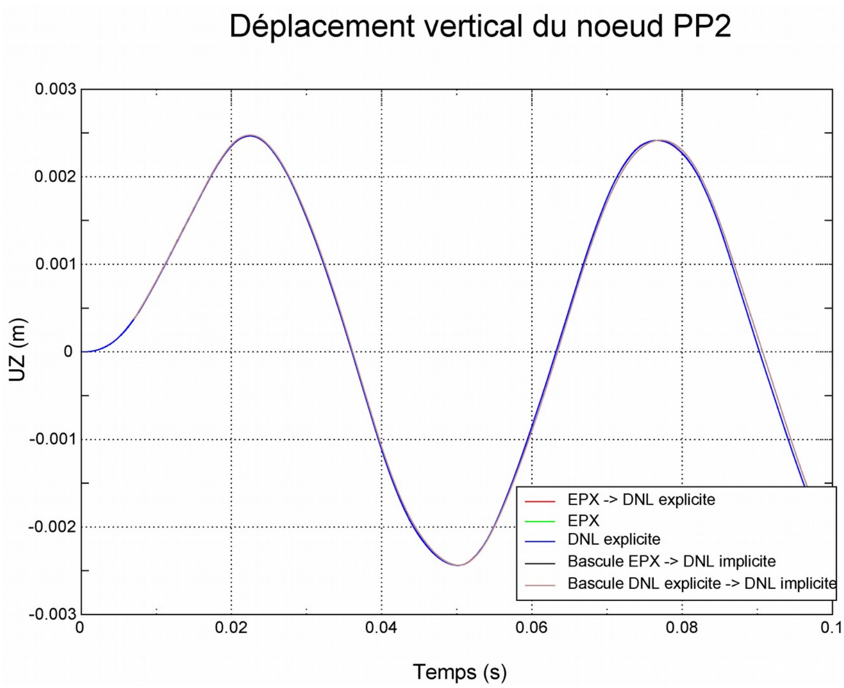
It will be thus possible to quantify:

- the precision during the second reading of data MED enters the codes and the good agreement of the models (curve 1),
- differences in model between Europlexus and *Code_Aster* (curves 2 and 3) with diagram in identical time,
- the differences between solution clarifies and solution with the rocker of diagram (curves 4 and 5).

The analysis on accelerations should amplify the variations, compared to the differences on displacement calculated.

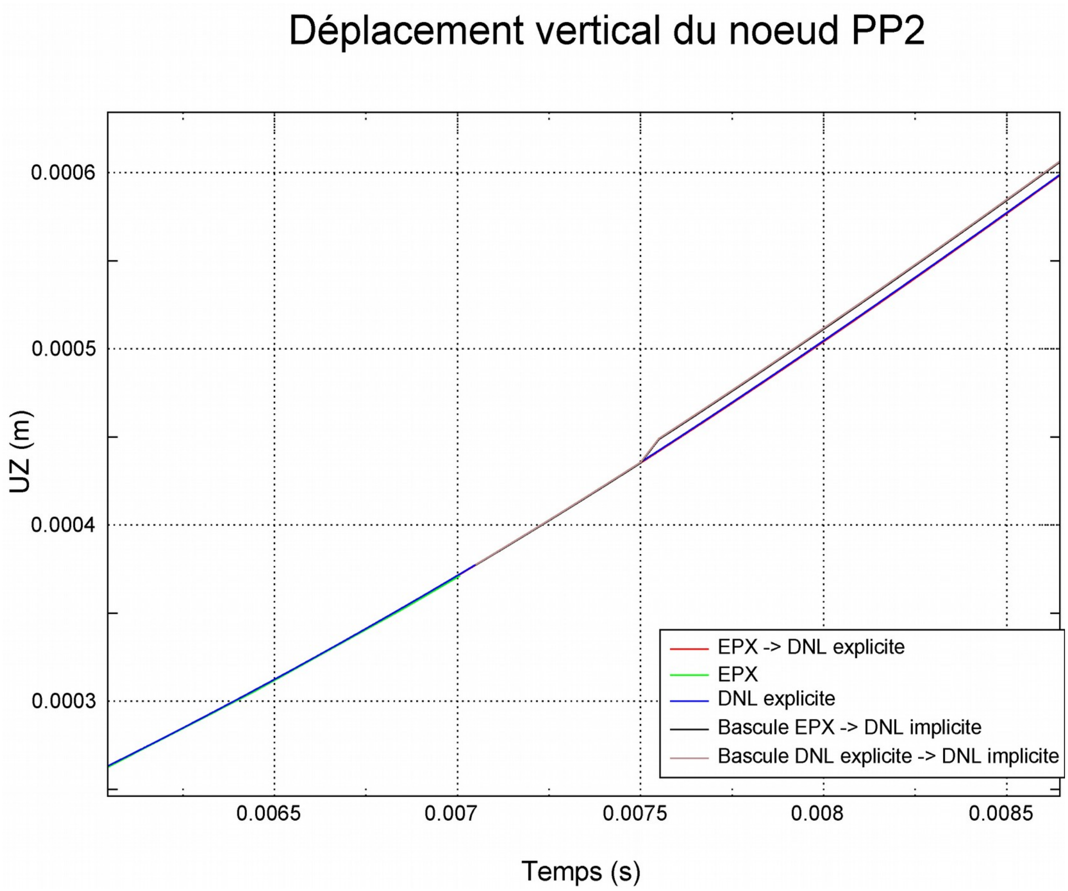
For the following graphs, one voluntarily increased the simulated duration of time, in order to have a more relevant analysis. In the command file of the CAS-test, this duration of simulation is much more reduced to decrease time CPU.

3.1.1 Comparison of calculated displacements



The answer is of oscillating type and the variations are weak. One observes just a very light dephasing between the answer explicit and implicit, which is due to the diagrams in time. The variation in amplitude is negligible.

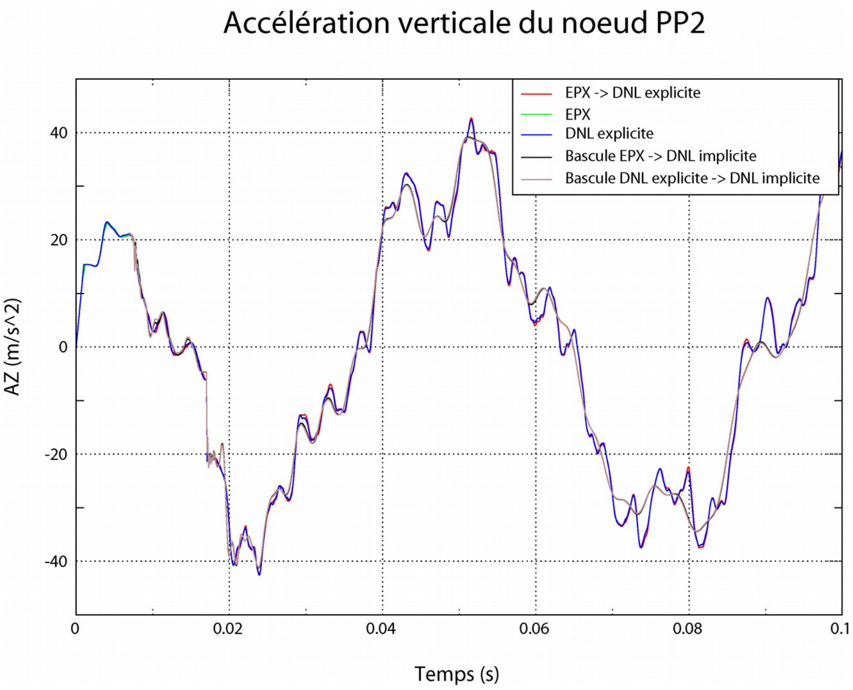
In order to supplement the analysis one will zoom in over the moment of rocker at moment 0.0075 S:



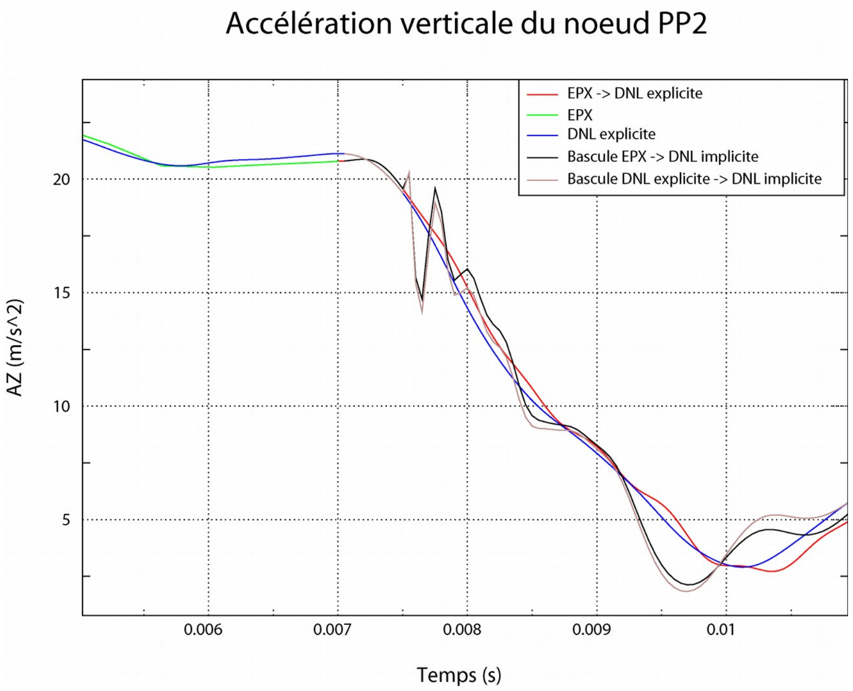
The rocker generates a light disturbance, but the answers remain the same ones, that one passes from Europlexus to *Code_Aster* (black curve) or that all the resolution is done in *Code_Aster* (curve chestnut).

It is important to note that this variation due to the rocker is not developing and that the answers remain very close to the reference solutions (without rocker).

3.1.2 Comparison of calculated accelerations



Accelerations take forms more kicked up a rumpus much than displacements, but the differences between the digital solutions remain moderate. More exactly, one sees well the influence of the diagram in implicit time which smoothes the answer (dissipative diagram standard HHT).



While zooming in over the moment of rocker, of the significant disturbances of acceleration appear. These digital oscillations cannot be completely destroyed, even while exploiting the parameters of the method of rocker of diagram (choice of the diagram at the time of the phase of balancing, parameter of this diagram, choice of the diagram before and after the rocker…). In fact, one could check that these oscillations are very largely caused by the change of matrix of mass: indeed, into explicit one uses a matrix of lumpée mass, whereas in implicit it is the matrix of consistent mass which is chosen.

At the time of the rocker, one passes brutally from a matrix of mass to the other and that comes to disturb the solution. The strategy of rebalancing does not completely manage to gum this jump.
A parade could be to rock gradually of a matrix of mass to the other, by using on some steps of time a variable matrix of mass which would be a linear combination of the two matrices (lumpée and consistent). The interest of this algorithmic evolution will remain to be been quantified on this CAS-test, for example.

3.2 Values tested

One will test the values obtained (displacements and accelerations) at the final moment: $0,007\,s$.
Each value tested will be in fact the absolute value of the relative difference between the result to test and the reference solution considered. This formula must tend towards 0 and it is directly a relative value, which explains why in the operator `TEST_FONCTION` one specifies `CRITERE=' ABSOLU'` because, without that, one would seek to make relative the value for the second time.
In practice, these values tested can tend towards 0 only if the variation enters the same calculation carried out with *Code_Aster* or Europlexus is null, which is not the case. More exactly, the variations for the solutions with rocker in time can be less only the differences between the two reference solutions (complete calculation with Europlexus and complete calculation with *Code_Aster* into explicit).
One thus starts by measuring the relative differences between the two reference solutions. In displacement, one a: $2,656188.10^{-3}$ and in acceleration: $0,016270437$
Then, one will analyze the relative variations induced by the resumption of calculation between Europlexus and *Code_Aster* (clarifies, therefore without rocker). In displacement, one a: $4,93101.10^{-04}$ and in acceleration: $0,0380$.
The variations induced by the rocker in time should be of the same order of magnitude. Indeed, the rocker cannot correct these variations inherent in the differences between the codes.
One starts by comparing the solution with Europlexus rocker towards *Code_Aster* implicit. In displacement, there is a relative variation of: $5,02195.10^{-04}$ and in acceleration: $0,019848325$.
Lastly, one gives the relative variations with the solution obtained by rocker clarifies towards implicit, but while always remaining in *Code_Aster* . In displacement, there is a relative variation of: $0,011460178$ and in acceleration: $0,045500117$.
One notices that the variations in accelerations are larger than those on displacements, which is logical because displacements are quantities more regular than accelerations, as one can check it on the graphs of the paragraphs 3.1.1 and 3.1.2 .
Then, it is noted that on displacements, the rocker introduces very little disturbance, whereas on accelerations, of the oscillations, certainly quenched, appear. After analysis, it proves that they are mainly due on the way brutal of a matrix of mass lumpée to a consistent matrix.

Concerning the calculation of SRO, one will calculate L ‘ maximum relative variation (on all the beach of frequency and for a damping are equivalent of 5 %) with the reference solution, that it is for the SRO obtained from `OBSERVATION` and of `FILING` . These relative variations are about 5 to 8 % and are ascribable with the rocker and the differences in step of time when the data input of the SRO are filed.

4 Synthesis

This CAS-test makes it possible to validate the continuation of calculations while passing from Europlexus with *Code_Aster*, on a model of reinforced concrete building. More precisely, one starts by validating the second reading of fields to the nodes or at the points of Gauss to continue by a calculation clarifies with `DYNA_NON_LINE` . Then, one validates this continuation while rocking towards a diagram in implicit time.
The variations observed are satisfactory and coherent with the differences in modeling between the codes (mainly on the level of the matrix of mass which can be consistent or lumpée). One validates also postprocessings of the type SRO calculated on the data resulting from `FILING` or of`OBSERVATION`.