

## SSNV206 - Triaxial compression test: models LETK and LKR

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### Summary

This test makes it possible to validate the models LETK and LKR in rock mechanics. It is about a triaxial compression test in pure mechanics or drained condition. Calculations are carried out only on the solid part of the ground without hydraulic coupling. One applies a level of confinement of  $5 \text{ MPa}$ . By reason of symmetry, one is interested only in the eighth of a sample subjected to a triaxial compression test. Modeling is axisymmetric.

## 1 Description of modelings

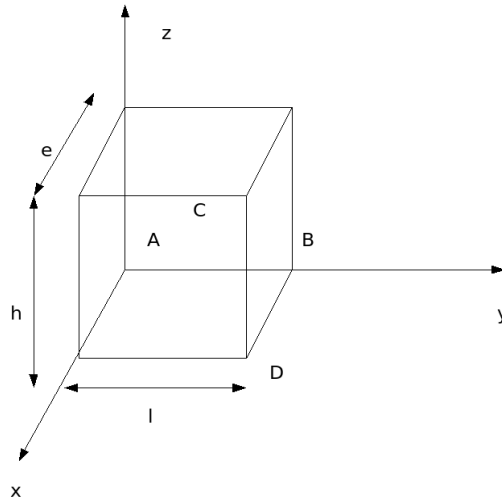
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- Modeling a: the local algorithm of integration of the model explicit, is classified like specific thereafter: model LETK.
- Modeling b: the local algorithm of integration of the model is implicit with the local matrix jacobienne obtained by disturbance: model LETK.
- Modeling C: The local algorithm of integration of the model is implicit with the local matrix jacobienne obtained analytically: model LETK.
- Modeling D: The local algorithm of integration of the model explicit, is classified like specific thereafter. The loading is applied 100 times more slowly to propose the role of viscosity in the model: model LETK.
- Modeling E: The local algorithm of integration of the model is implicit with the local matrix jacobienne obtained analytically. The loading is applied 100 times more slowly to propose the role of viscosity in the model: model LETK.
- Modelisation F : The local algorithm of integration of the model explicit, is classified like specific thereafter, pas de imposed temperature : model LKR.
- Modeling G : The local algorithm of integration of the model is implicit with the local matrix jacobienne obtained by disturbance, pas de imposed temperature : model LKR .
- Modeling H : The local algorithm of integration of the model is implicit with the local matrix jacobienne obtained analytically, pas de imposed temperature, not of coupling between the plastic and viscoplastic mechanism ( COUPLAGE\_P\_VP = 0. ) : model LKR .
- Modeling I : The local algorithm of integration of the model explicit, is classified like specific thereafter, increasing temperature (0°C-100°C) imposed via AFFE\_VARC : model LKR .
- Modeling J : The local algorithm of integration of the model is implicit with the local matrix jacobienne obtained analytically , increasing temperature (0°C-100°C) imposed via AFFE\_VARC : model LKR .
- Modeling K : The local algorithm of integration of the model explicit, is classified like specific thereafter. The loading is applied 100 times more slowly to propose the role of viscosity in the model, pas de imposed temperature : model LKR .
- Modeling L : The local algorithm of integration of the model is implicit with the local matrix jacobienne obtained analytically. The loading is applied 100 times more slowly to propose the role of viscosity in the model, pas de imposed temperature : model LKR.

They are tests of nonregression. 12 modelingS converge towards concordant solutions for fine discretizations of the loading applied.

## 2 Problem of reference

### 2.1 Geometry



height:  $h = 1\text{ m}$   
width:  $l = 1\text{ m}$   
thickness:  $e = 1\text{ m}$

Coordinates of the points (in meters):

	<i>A</i>	<i>B</i>	<i>C</i>	<i>D</i>
<i>x</i>	0.	0.	0.5	1.
<i>y</i>	0.	1.	0.5	1.
<i>z</i>	0.	0.	0.5	0.

## 2.2 PropertyS materials for model LETK

Pa	= 0.1
NELAS	= 0.
SIGMA_C	= 12.
H0_EXT	= 1.10292
GAMMA_CJS	= 0.8
XAMS	= 0.1
ETA	= 0.04
A_0	= 0.25
A_E	= 0.60
A_PIC	= 0.4
S_0	= 0.0005
M_0	= 0.01
M_E	= 2.
M_PIC	= 6.
M_ULT	= 0.61
XI_ULT	= 0,365
XI_E	= 0,028
XI_PIC	= 0,015
MV_MAX	= 3.
XIV_MAX	= 0.0039
With	= 1.5e-12
NR	= 4.5
SIGMA_P1	= 57.8
MU0_V	= 0.1
XI0_V	= 0.3
MU1	= 0.1
XI1	= 0.3

## 2.3 PropertyS materials for model LKR

Pa	= .1	
NELAS	= 0.	
SIGMA_C	= 12.	
BETA	= 1.5	
GAMMA	= .8	
V_1	= 2.1	
V_2	= 2.2	
A_2	= .65	
M_0	= .1	
M_1	= 4.1	
Q_1	= 45.	
XI_1	= .017	
XI_2	= .030	
XI_5	= .0039	
F_P	= .1	
With	= 1.5e-13	
NR	= 4.5	
RHO_1	= .1	
RHO_2	= 2.	
RHO_4	= .3	
R_Q	= 0.	(except for modelings I and J, = 1.e-4)
R_M	= 0.	(except for modelings I and J, = 1.e-4)
R_S	= 0.	(except for modelings I and J, = 1.e-3)
R_X1	= 0.	(except for modelings I and J, = 1.e-2)
R_X2	= 0.	(except for modelings I and J, = 1.e-2)
R_X5	= 0.	(except for modelings I and J, = 1.e-2)
Z	= 0.	(except for modelings I and J, = 1000.)
COUPLAGE_P_VP	= 1.	(except for modeling H, = 0.)

## 2.4 Initial conditions, boundary conditions, and loading

### Phase 1:

One brings the sample in a homogeneous state:  $\sigma_{xx}^0 = \sigma_{yy}^0 = \sigma_{zz}^0$ , by imposing the corresponding confining pressure on the front, side right-hand side and higher faces. Displacements are blocked on the faces postpones ( $u_x = 0$ ), side left ( $u_y = 0$ ) and lower ( $u_z = 0$ ).

### Phase 2:

One maintains displacements blocked on the faces postpones ( $u_x = 0$ ), side left ( $u_y = 0$ ) and lower ( $u_z = 0$ ), as well as the confining pressure on the front faces and side right-hand side. One applies a displacement imposed to the higher face:  $u_z(t)$ , in order to obtain a deformation  $\varepsilon_{zz} = -6$  over one duration of 6e3 seconds for modelings A, B, C, F, G, H, I and J and a duration of 6e5 seconds for modelings D, E, K and L.

For modelings I and J, an increasing temperature is imposed in phases 1 and 2 via the keyword factor AFFE\_VARC. One assembles 0°C to 50°C during phase 1 and of 50°C to 100°C during phase 2.

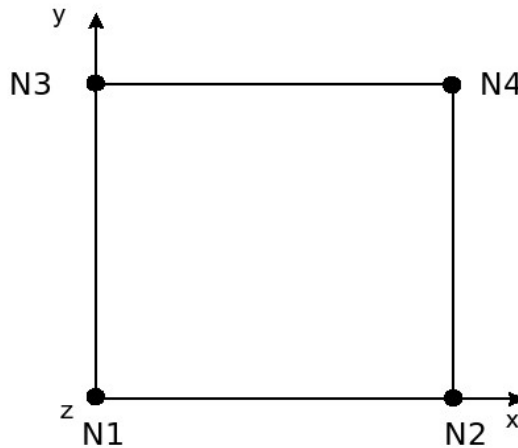
## 3 Reference solutions

The reference solutions are obtained by fine discretization of the loading. There does not exist a priori of known analytical solutions for integration Dbe models LETK and LKR according to a triaxial compression test of compression.

## 4 Modeling A

### 4.1 Characteristic of modeling

AXIS :



Cutting: 1 in height, 1 in width.

### 4.2 Characteristic of the grid

Many nodes: 4  
Many meshes and types: 1 QUAD4 and 4 SEG2

### 4.3 Sizes tested and results

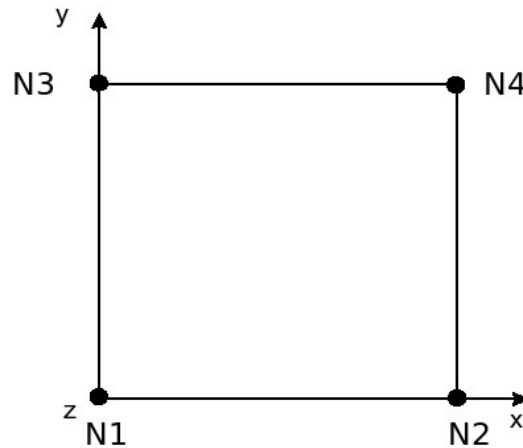
The values are tested in nonregression with a tolerance given of 0,1% .

Localization	Moment	Constraint (MPa)	Aster
Not $N4$	7000.	$\sigma_{yy}$	- 5,000
	13000.	$\sigma_{yy}$	- 11,941
Localization	Moment	Déplacement (m)	Aster
Not $N4$	7000.	$DX$	-7.6 10-4
	13000.	$DX$	3,020 10-2

## 5 Modeling B

### 5.1 Characteristic of modeling

AXIS :



Cutting: 1 in height, 1 in width.

### 5.2 Characteristic of the grid

Many nodes: 4  
Many meshes and types: 1 QUAD4 and 4 SEG2

### 5.3 Sizes tested and results

The values are tested in nonregression with a tolerance given of 0,1% .

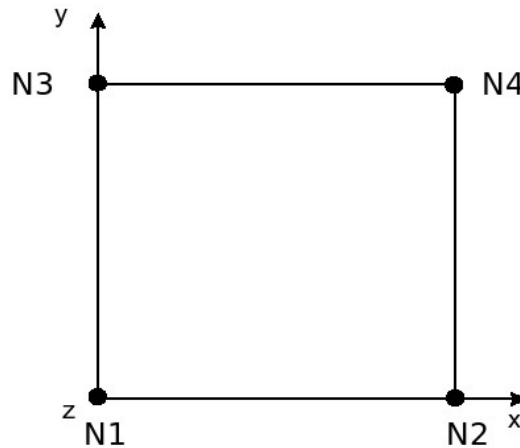
Localization	Moment	Constraint (MPa)	Aster
Not <i>N4</i>	7000.	$\sigma_{yy}$	- 5,000
	13000.	$\sigma_{yy}$	- 11,945
Localization	Moment	Déplacement (m)	Aster
Not <i>N4</i>	7000.	<i>DX</i>	-7.6 10-4
	13000.	<i>DX</i>	3,026 10-2



## 6 Modeling C

### 6.1 Characteristic of modeling

AXIS :



Cutting: 1 in height, 1 in width.

### 6.2 Characteristic of the grid

Many nodes: 4  
Many meshes and types: 1 QUAD4 and 4 SEG2

### 6.3 Sizes tested and results

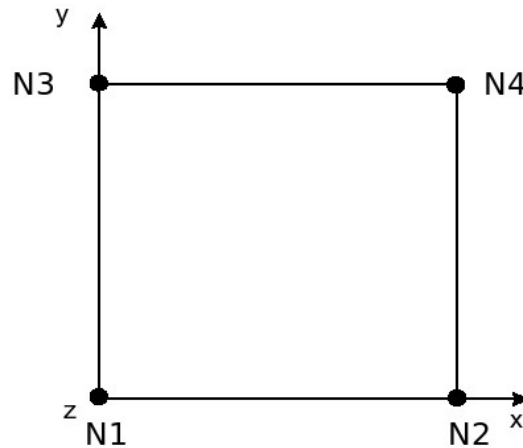
The values are tested in nonregression with a tolerance given of 0,1% .

Localization	Moment	Constraint (MPa)	Aster
Not <i>N4</i>	7000.	$\sigma_{yy}$	- 5,000
	13000.	$\sigma_{yy}$	- 11,945
Localization	Moment	Déplacement (m)	Aster
Not <i>N4</i>	7000.	<i>DX</i>	-7.6 10-4
	13000.	<i>DX</i>	3,026 10-2

## 7 Modeling D

### 7.1 Characteristic of modeling

AXIS :



Cutting: 1 in height, 1 in width.

### 7.2 Characteristic of the grid

Many nodes: 4  
Many meshes and types: 1 QUAD4 and 4 SEG2

### 7.3 Sizes tested and results

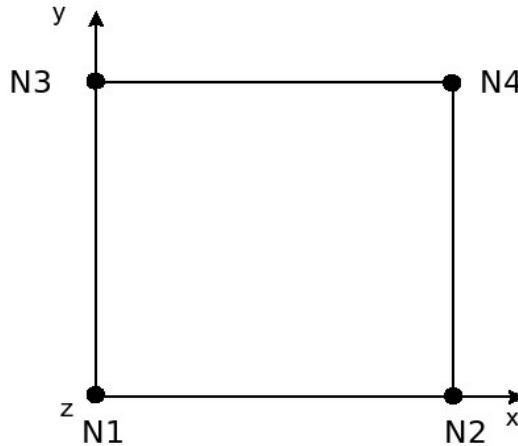
The values are tested in nonregression with a tolerance given of 0,1% .

Localization	Moment	Constraint (MPa)	Aster
Not <i>N4</i>	7000.	$\sigma_{yy}$	- 5,000
	13000.	$\sigma_{yy}$	- 12.01
Localization	Moment	Déplacement (m)	Aster
Not <i>N4</i>	7000.	<i>DX</i>	-7.6 10-4
	13000.	<i>DX</i>	2.98 10-2

## 8 Modeling E

### 8.1 Characteristic of modeling

AXIS :



Cutting: 1 in height, 1 in width.

### 8.2 Characteristic of the grid

Many nodes: 4  
Many meshes and types: 1 QUAD4 and 4 SEG2

### 8.3 Sizes tested and results

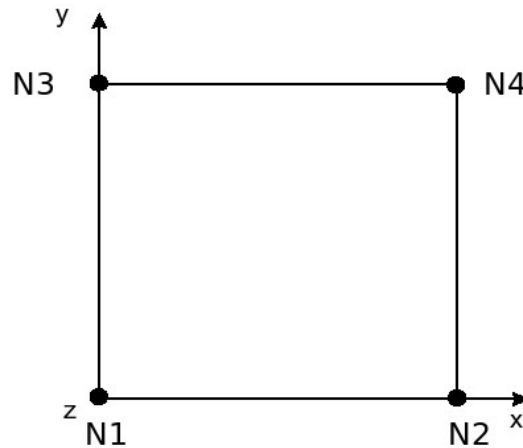
The values are tested in nonregression with a tolerance given of 0,1 % .

Localization	Moment	Constraint (MPa)	Aster
Not N4	7000.	$\sigma_{yy}$	- 5,000
	13000.	$\sigma_{yy}$	- 12.01
Localization	Moment	Displacement (m)	Aster
Not N4	7000.	$DX$	-7.6 10-4
	13000.	$DX$	3.00 10-2

## 9 Modeling F

### 9.1 Characteristic of modeling

AXIS :



Cutting: 1 in height, 1 in width.

### 9.2 Characteristic of the grid

Many nodes: 4  
Many meshes and types: 1 QUAD4 and 4 SEG2

### 9.3 Sizes tested and results

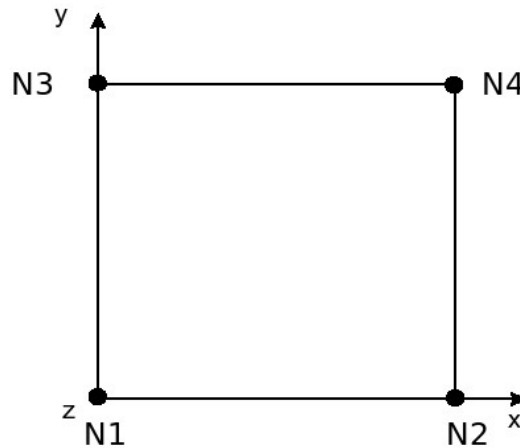
The values are tested in nonregression with a tolerance given of 0,1% .

Localization	Moment	Constraint (MPa)	Aster
Not N 4	7000.	$\sigma_{yy}$	- 5,000
	13000.	$\sigma_{yy}$	-11.47
Localization	Moment	Displacement (m)	Aster
Not N 4	7000.	$DX$	-7.6 10-4
	13000.	$DX$	2.91 10-2

## 10 Modeling G

### 10.1 Characteristic of modeling

AXIS :



Cutting: 1 in height, 1 in width.

### 10.2 Characteristic of the grid

Many nodes: 4  
Many meshes and types: 1 QUAD4 and 4 SEG2

### 10.3 Sizes tested and results

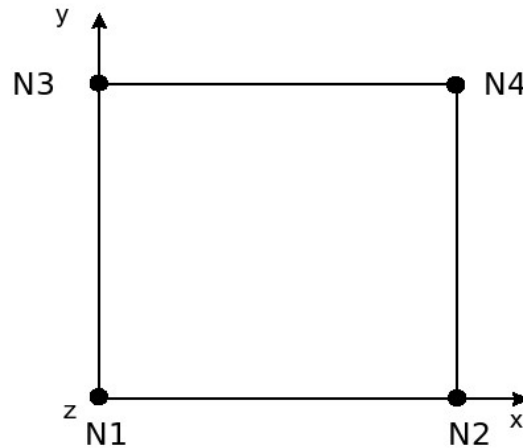
The values are tested in nonregression with a tolerance given of 0,1% .

Localization	Moment	Constraint (MPa)	Aster
Not N4	7000.	$\sigma_{yy}$	- 5,000
	13000.	$\sigma_{yy}$	-11.47
Localization	Moment	Displacement (m)	Aster
Not N4	7000.	$DX$	-7.6 10-4
	13000.	$DX$	2.92 10-2

## 11 Modeling H

### 11.1 Characteristic of modeling

AXIS :



Cutting: 1 in height, 1 in width.

### 11.2 Characteristic of the grid

Many nodes: 4  
Many meshes and types: 1 QUAD4 and 4 SEG2

### 11.3 Sizes tested and results

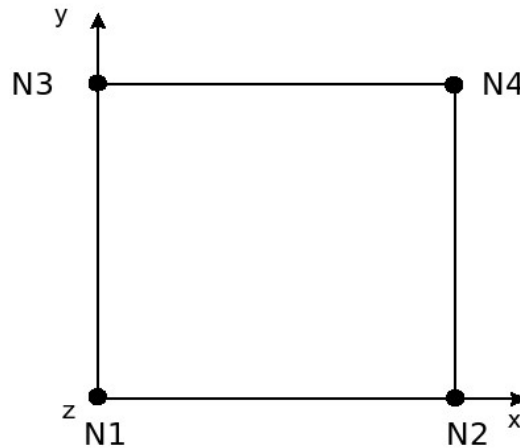
The values are tested in nonregression with a tolerance given of 0,1% .

Localization	Moment	Constraint (MPa)	Aster
Not N 4	7000.	$\sigma_{yy}$	- 5,000
	13000.	$\sigma_{yy}$	-14.02
Localization	Moment	Displacement (m)	Aster
Not N 4	7000.	$DX$	-7.6 10-4
	13000.	$DX$	2.90 10-2

## 12 Modeling I

### 12.1 Characteristic of modeling

AXIS :



Cutting: 1 in height, 1 in width.

### 12.2 Characteristic of the grid

Many nodes: 4  
Many meshes and types: 1 QUAD4 and 4 SEG2

### 12.3 Sizes tested and results

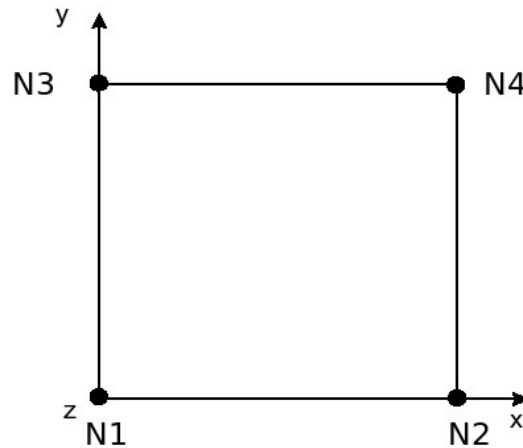
The values are tested in nonregression with a tolerance given of 0,1% .

Localization	Moment	Constraint (MPa)	Aster
Not N4	7000.	$\sigma_{yy}$	- 5,000
	13000.	$\sigma_{yy}$	-14.19
Localization	Moment	Displacement (m)	Aster
Not N4	7000.	$DX$	-7.6 10-4
	13000.	$DX$	2.85 10-2

## 13 Modeling J

### 13.1 Characteristic of modeling

AXIS :



Cutting: 1 in height, 1 in width.

### 13.2 Characteristic of the grid

Many nodes: 4  
Many meshes and types: 1 QUAD4 and 4 SEG2

### 13.3 Sizes tested and results

The values are tested in nonregression with a tolerance given of 0,1% .

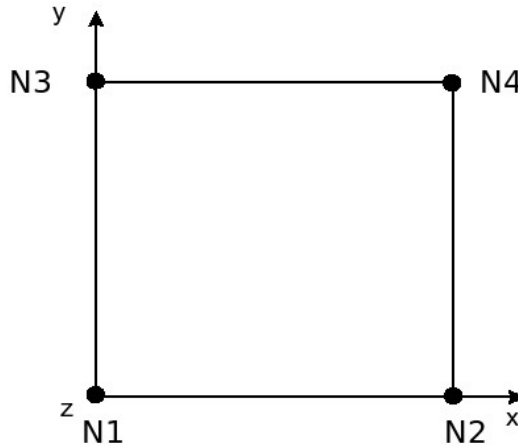
Localization	Moment	Constraint (MPa)	Aster
Not N 4	7000.	$\sigma_{yy}$	- 5,000
	13000.	$\sigma_{yy}$	-14.19
Localization	Moment	Displacement (m)	Aster
Not N 4	7000.	$DX$	-7.6 10-4
	13000.	$DX$	2.85 10-2



## 14 Modeling K

### 14.1 Characteristic of modeling

AXIS :



Cutting: 1 in height, 1 in width.

### 14.2 Characteristic of the grid

Many nodes: 4  
Many meshes and types: 1 QUAD4 and 4 SEG2

### 14.3 Sizes tested and results

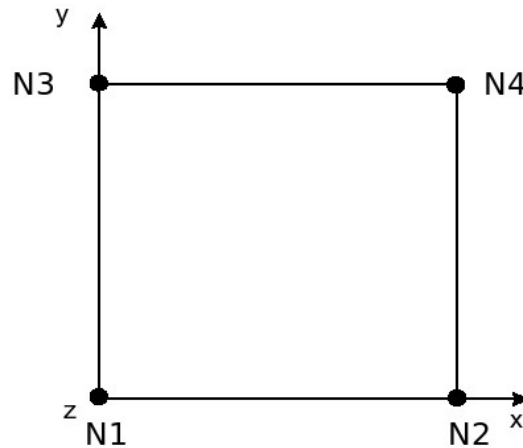
The values are tested in nonregression with a tolerance given of 0,1% .

Localization	Moment	Constraint (MPa)	Aster
Not N4	7000.	$\sigma_{yy}$	- 5,000
	13000.	$\sigma_{yy}$	-11.53
Localization	Moment	Displacement (m)	Aster
Not N4	7000.	$DX$	-7.6 10-4
	13000.	$DX$	2.89 10-2

## 15 Modeling L

### 15.1 Characteristic of modeling

AXIS :



Cutting: 1 in height, 1 in width.

### 15.2 Characteristic of the grid

Many nodes: 4  
Many meshes and types: 1 QUAD4 and 4 SEG2

### 15.3 Sizes tested and results

The values are tested in nonregression with a tolerance given of 0,1% .

Localization	Moment	Constraint (MPa)	Aster
Not N 4	7000.	$\sigma_{yy}$	- 5,000
	13000.	$\sigma_{yy}$	-11.53
Localization	Moment	Displacement (m)	Aster
Not N 4	7000.	$DX$	-7.6 10-4
	13000.	$DX$	2.90 10-2

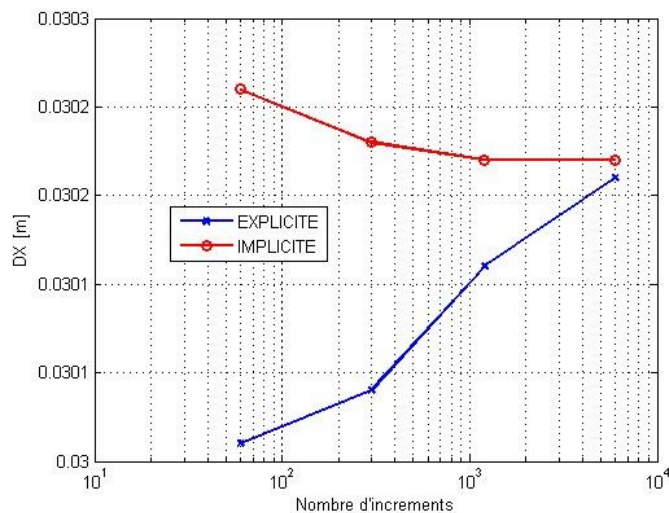
## 16 Summary of the results

They are tests of nonregression developedS to validate the model LETK in pure mechanics. The comparison between the two diagrams of integration makes it possible to identify certain tendencies on the profiles of convergence.

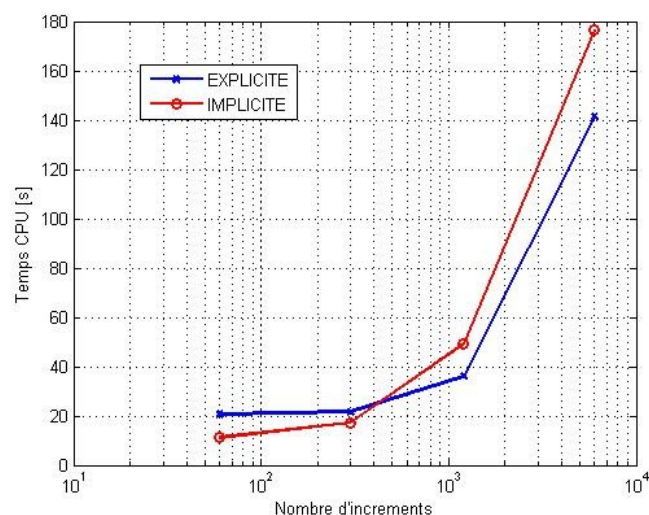
An explicit diagram of integration makes it possible for a fine discretization of the loading to guarantee converged results and an execution time machine less than the implicit scheme. It is on the other hand difficult to quantify the level of smoothness of the loading to be applied to guarantee the convergence of the studies with a diagram of explicit integration.

The implicit diagram of integration guarantees a level of precision higher than the explicit diagram for the same discretization of loading. It also makes it possible to have a local tangent operator consist. These advantages thus ensure on a broad range of discretizations of the loading a convergence on the results got with the implicit scheme.

The following figures illustrate the preceding sales leaflet.



**Illustration 1: Maximum side displacement of the sample of laboratory during a triaxial compression test of compression according to the level of discretization of the loading**



**Illustration 2: Time CPU cumulated for the triaxial compression test of compression according to the level of discretization of the loading**

