SSNV207 – Cyclic shear test including of the microphone-discharges with the law of Hujeux

Summary

One is carried out cyclic shear test, controlled in force, pure mechanics (équivalent under hydraulic conditions drained) with *the law of Hujeux*. During the cycles of load-discharge, microphone-discharges are carried out to test the capacity of the law of Hujeux to find the modulus of rigidity hammer-hardened before this microphone-discharge. The calculated solutions are compared with results resulting from Code_Aster for a way of identical cyclic loading without the microphone-discharges.

1 Problem of reference

1.1 Geometry

The cyclic shear test is carried out on a single point of Gauss. The test is thus controlled completely in imposed constraints and deformations.

1.2 Material properties of the sand of Hostun

The elastic properties are:

- isotropic module of compressibility: $K=516\,MPa$
- modulus of rigidity: $\mu=238\,MPa$

The unelastic properties (model of Hujeux) were established by F.Lopez-Caballero **[1]** :

- power of the non-linear elastic law: $n_e=0.4$ (– > elastic linear)
- $\beta=24.$
- $d=2.5$
- $b=0.2$
- angle of friction: $\phi=33°$
- characteristic angle: $\Psi=33°$
- critical pressure: $P_{CO}=-1000\,kPa$
- pressure of reference: $P_{ref}=-1000\,kPa$
- elastic ray of the isotropic mechanism: $r_i^{ela}=10^{-3}$
- elastic ray of the mechanism déviatoire: $r_d^{ela}=0.005$
- $a_{mon}=0.008$
- $a_{cyc}=0.0001$
- $c_{mon}=0.18$
- $c_{cyc}=0.09$
- $r_{hys}=0.05$
- $r_{mob}=0.9$
- $x_m=1.$
- $dila=1.$

1.3 Boundary conditions and loadings

The cyclic shear test presented here is carried out in pure mechanical conditions, via the order `SIMU_POINT_MAT`. One imposes at the local level on the point of Gauss considered a stress shear σ_{xy} , variable during the test. Components σ_{xx} , σ_{yy} , σ_{zz} are constant during the test and equal to the value of confining pressure of $P_0=-50\,kPa$. The test carried out corresponds to a direct shear test.

In the model considered, the imposed constraints are thus the following ones:

- Constant confining pressure:
$$P_0=\sigma_{xx}=\sigma_{yy}=\sigma_{zz}=-50\,kPa$$
- Conditions of loading:
$\sigma_{xy}=F1(t)$, t corresponding to the fictitious time of modeling.

The loading is carried out in two phases:

- An isotropic state of stresses, $P_o=-50\,kPa$, is affected initially at the point of Gauss considered;
- A shear stress, σ_{xy} , is imposed and varies between $t=0.$ and $t=40$ according to the function $F1(t)$.

A test of nonregression is carried out with Code_Aster where one also carries out a cyclic direct shear test but microphone-discharge. Shear stresses following the function then $F2(t)$.

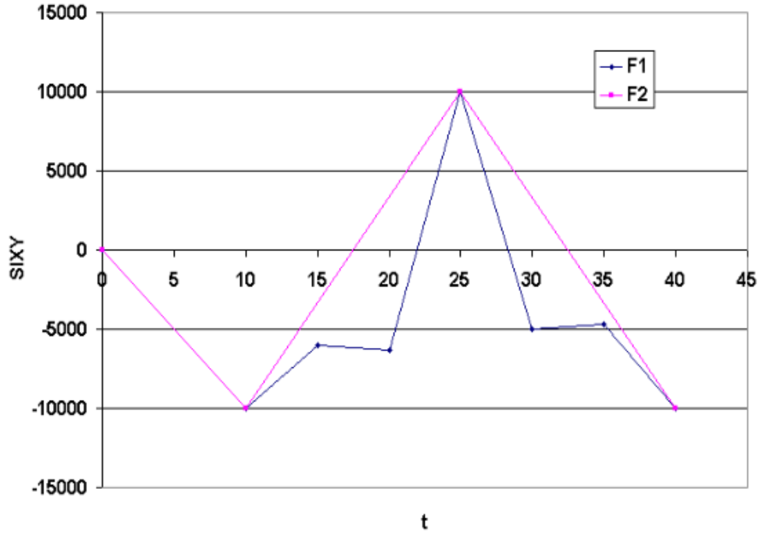

Figure 1.3-a: Evolution of $F1$ and $F2$ according to t

1.4 Results

The solutions post-are treated with the point of Gauss, in terms of distortion ε_{xy} , of cumulated plastic voluminal deformation, ε_v^p % , and of coefficients of cyclic work hardening déviatoire, r_d^c .

The validation is carried out by comparison with the solution obtained for the way of loading without the microphone-discharges via Code_Aster.

2 Modeling A

2.1 Characteristics of modeling

Modeling is three-dimensional $3D$ and non-linear statics.

The cyclic shear test with microphone-discharges is controlled in constraints, via σ_{xy}, while imposing a constant confining pressure, $P_0 = -50\,kPa$. The automatic subdivision of the step of time is only activated to manage the situations of nonconvergence of local integration.
In the integration of the equilibrium equations, one asks for a reactualization of the tangent matrix, which is provided by the routines of the law of Hujeux and accelerates convergence considerably. One also asks for the subdivision of the step of time (order `DEFI_LIST_INST`) to treat the situations of failure of local integration due to increments of too large loading. This functionality is *largely recommended*.

2.2 Sizes tested and results

The solutions are calculated at the point of Gauss and are compared with Code_Aster references for a way of identical loading without the microphone-discharges. They are given in terms of deformations ε_{xy}, of cumulated plastic voluminal deformation ε_v^p and of coefficients of cyclic work hardening déviatoire $\left(r_{ela}^{d,c} + r_{dev}^{c}\right)$, and recapitulated in the following tables:

ε_{xy}

σ_{xy} [Pa]	Type of Reference	Value of reference	Tolerance ($\%$)
$-1E4$	AUTRE_ASTER	$-1.95E-4$	1.0
$1E4$	AUTRE_ASTER	$1.94E-4$	1.0
$-1E4$	AUTRE_ASTER	$1.95E-4$	1.0

ε_v^p

σ_{xy} [Pa]	Type of Reference	Value of reference	Tolerance ($\%$)
$-1E4$	AUTRE_ASTER	$-1.35E-5$	2.0
$1E4$	AUTRE_ASTER	$-4.28E-5$	1.0
$-1E4$	AUTRE_ASTER	$-7.21E-5$	1.0

$\left(r_{ela}^{d,c} + r_{dev}^{c}\right)$ (Plan XY)

σ_{xy} [Pa]	Type of Reference	Value of reference	Tolerance ($\%$)
$1E4$	AUTRE_ASTER	0.23	1.0
$-1E4$	AUTRE_ASTER	0.23	1.0

2.3 Comments

The comparison between the solutions with or without microphone-discharge is particularly good, with generally less 1% of error.

3 Summary of the results

One represents as information in the following curves the various comparisons between Code_Aster for the two types of loading stated in the document (AD : With discharge; SD : Without discharge) and GEFDYN, the software finite elements developed at the MSSMat laboratory of the Central School Paris. The curves take again the quantities tested beforehand in the preceding section, namely ε_{xy} (figure 3-a), ε_v^p (figure 3-b) and $\left(r_{ela}^{d,c}+r_{dev}^{c}\right)$ (figure 3-c).

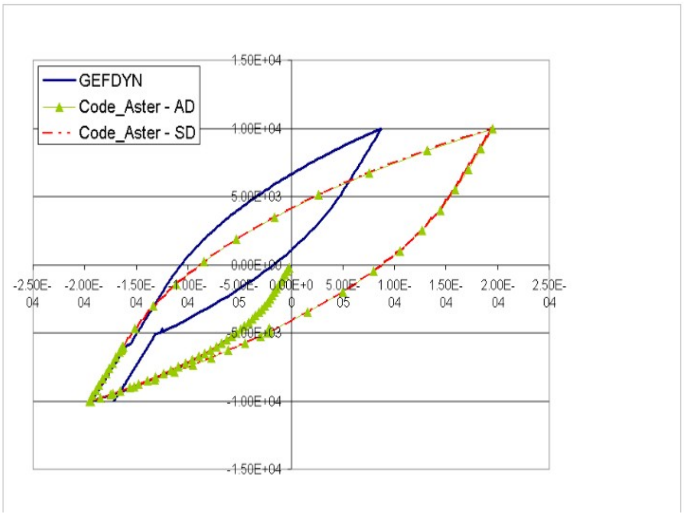

Figure **3-a** : *Constraint déviatoire according to the distortion: comparison of the solutions of Code_Aster and GEFDYN*

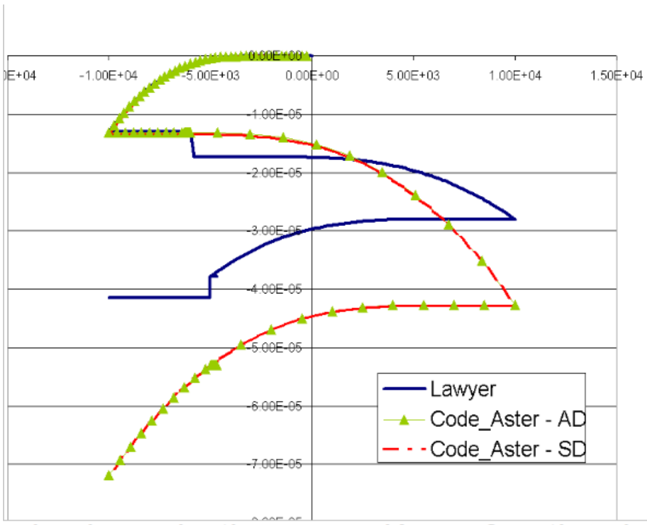

Figure **3-b** : *plastic voluminal deformation cumulated according to the constraint déviatoire: comparison enters the solutions of Code_Aster and GEFDYN.*

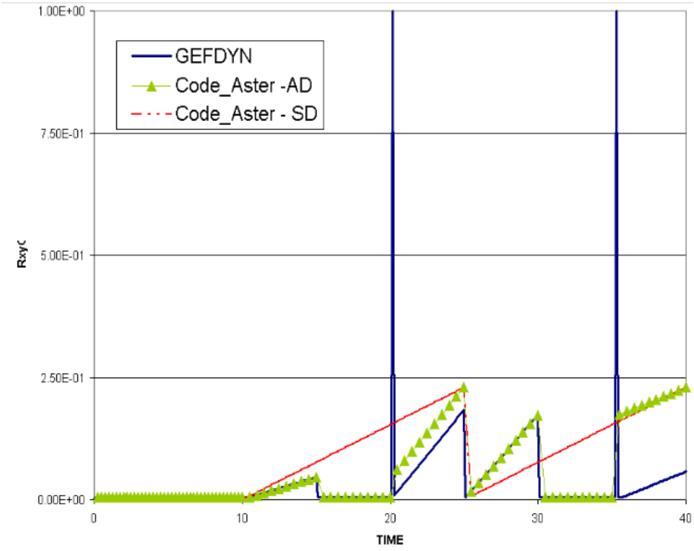

Figure **3-c**: *cyclic ray déviatoire according to fictitious time: comparison enters the solutions of Code_Aster and GEFDYN.*

The differences observed between GEFDYN and Code_Aster propose a management suspects by GEFDYN of the work hardening of the cyclic circles déviatoires in the plan of imposed shearing. Whereas the model predicts an elastic microphone-discharge, GEFDYN proposes a complete work hardening of the cyclic circle déviatoire until perfect plasticity, before defining a cyclic circle déviatoire in elastic ray. The behavior of Code_Aster respects the elastic character of this discharge and takes again at exit of this microphone-discharge a slope of work hardening identical to that obtained before.

The development team of GEFDYN is advised divergences noted between the two computer codes.

[1] Lopez Caballero F. “Influence of the Behavior Non Linéaire of the Ground on the Seismic Movements Induced in Géo-Structures”. Thesis of Doctor, Central School Paris, Châtenay Malabry, France, 2003