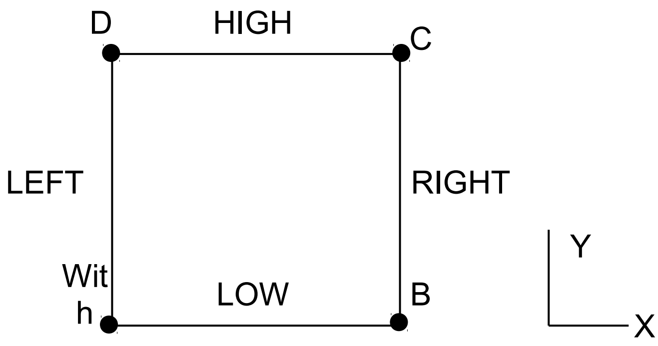
SSNV208 – Biaxial test drained with the law of Hujeux

Summary

One is carried out *biaxial test in pure mechanics* (equivalent under drained hydraulic conditions) with *the law of Hujeux*. The calculated solutions are compared with results resulting from the code finite elements GEFDYN of the Central School Paris.

1 Problem of reference

1.1 Geometry



The biaxial test is carried out on only one isoparametric finite element of square form `QUAD8`, group of mesh named $BLOC$. The length of each edge is worth 1m. The various sides of this square are named groups of mesh $HAUT$, BAS, $DROIT$ and $GAUCHE$. The group of meshs $COTE$ contains the groups of mesh in addition $DROIT$ and $GAUCHE$; the group of mesh $APPUI$ the group of mesh BAS.

1.2 Material properties of the sand of Hostun

The elastic properties are:

- isotropic module of compressibility: $K=148\,MPa$
- modulus of rigidity: $\mu=68\,MPa$

The unelastic properties (model of Hujeux) result from the report of thesis of K.Hamadi **[2]** and correspond to sand of not very dense Hostun:

- power of the non-linear elastic law: $n_e=0.$ (linear rubber band)
- $\beta=30.$
- $d=2.5$
- $b=0.2$
- angle of friction: $\phi=33°$
- characteristic angle: $\Psi=33°$
- critical pressure: $P_{CO}=-400\,kPa$
- pressure of reference: $P_{ref}=-1000\,kPa$
- elastic ray of the isotropic mechanism: $r_{ela}^{s}=10^{-4}$
- elastic ray of the mechanism déviatoire: $r_{ela}^{d}=0.01$
- $a_{mon}=0.017$
- $a_{cyc}=0.0001$
- $c_{mon}=0.08$
- $c_{cyc}=0.04$
- $r_{hys}=0.05$
- $r_{mob}=0.9$
- $x_m=1.$
- $dila=1.$

1.3 Boundary conditions and loadings

The biaxial test presented here is carried out in modeling `D_PLAN`. Normal displacements with the study plan are thus worthless. One imposes on the test-tube a vertical displacement all while keeping the side pressure constant in the study plan. It can be drained (the pore water pressure of fluid does not vary during the test) or not-drained (one turns off the tap: the pore water pressure of fluid evolves in the sample). One is interested here in the drained case, simpler, because not utilizing the influence of the pore water pressure of the fluid. One chooses a modeling in pure mechanics then.

In the model considered, the square element represents a quarter of the sample. The boundary conditions are thus the following ones:
Conditions of symmetry:

- $u_y=0.$ on the group of mesh BAS
- $u_x=0.$ on the group of mesh $GAUCHE$

Conditions of side pressure:

- $P_n=1.$ on the group of mesh $COTE$

Conditions of loading:

- $P_n=1.$ on the group of mesh $HAUT$
- $u_z=-1.$ on the group of mesh $HAUT$

The loading is carried out in two phases:

- An isotropic state of stresses, $P_o=100\,kPa$, is affected initially on the mesh $BLOC$;
- A vertical displacement is imposed on the group of meshs $HAUT$ and varies between $t=0.$ and $t=10.$ of $u_y=0.$ and $u_y=-0.2$ (total vertical deformation of 20%).

1.4 Results

The solutions post-are treated with the point C, in terms of constraint σ_{yy}, of total voluminal deformation ε_v and of coefficients of isotropic work hardening $\left(r_{ela}^{iso,m}+r_{iso}^{m}\right)$ and déviatoire $\left(r_{ela}^{d,m}+r_{dev}^{m}\right)$.

The validation is carried out by comparison with solutions GEFDYN provided by the Central School Paris (http://www.mssmat.ecp.fr/-GEFDYN,016-).

The elementary calculation of option is also carried out `PDIL_ELGA` for this problem of softening. This option of calculation makes it possible to consider the value maximum to allocate with the parameter of regularization `A1` mediums of second gradient of dilation `[R5.04.03]`. This value is a function of the parameters material, state of stresses and values of the internal variables at the moment of calculation [1].

1.5 Bibliographical references

[1] Foucault A. “ *Modeling of the cyclic behavior of the ground works integrating of the techniques of regularization ”.* Thesis of Doctor, Central School Paris, Châtenay Malabry, France, 2010.
[2] Hamadi K. “ *Modeling of the junctions and instabilities in the géomatériaux ones*”. Thesis of Doctor, Central School Paris, Châtenay Malabry, France, 2006

2 Modeling A

2.1 Characteristics of modeling

Modeling is two-dimensional with plane deformations D_PLAN and non-linear statics.
The vertical displacement imposed on the higher facet varies between 0 and $-0.2\mathrm{m}$ in 280 pas de time enters $t=0.$ and $t=10$. The automatic subdivision of the step of time is activated to manage the situations of nonconvergence of local integration.

The option of calculation INDL_ELGA, allowing to calculate the directions of the tensor of Rice, is also activated. The results provided by this option are tested in mode of not-regression.

The option of calculation PDIL_ELGA, allowing to calculate the values of the parameter A1_LC2, is also activated. The results provided by this option are tested in mode of not-regression.

2.2 Sizes tested and results

The solutions are calculated at the point C and compared with references GEFDYN. They are given in terms of constraint σ_{yy} , of total voluminal deformation ε_v and of coefficients of isotropic work hardening $\left(r_{ela}^{iso,m}+r_{iso}^m\right)$ and déviatoire $\left(r_{ela}^{d,m}+r_{dev}^m\right)$, and recapitulated in the following tables:

$\sigma_{yy}(kPa)$

ε_{zz}	TYPE	GEFDYN	Tolerance (%)
-1%	'SOURCE_EXTERNE'	-243.1	1.0
-2%	'SOURCE_EXTERNE'	-287.8	1.0
-5%	'SOURCE_EXTERNE'	-345.1	1.0
-10%	'SOURCE_EXTERNE'	-372.9	1.0
-20%	'SOURCE_EXTERNE'	-377.2	1.0

$\varepsilon_V=trace(\varepsilon)$

ε_{zz}	TYPE	GEFDYN	Tolerance (%)
-1%	'SOURCE_EXTERNE'	-4.07E-3	1.0
-2%	'SOURCE_EXTERNE'	-6.04E-3	1.0
-5%	'SOURCE_EXTERNE'	-8.18E-3	2.0
-10%	'SOURCE_EXTERNE'	-7.19E-3	6.0
-20%	'SOURCE_EXTERNE'	-1.87E-3	4.0

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

ε_{zz}	TYPE	GEFDYN	Tolerance (%)
-1%	'SOURCE_EXTERNE'	0,398	2.0
-2%	'SOURCE_EXTERNE'	0,455	1.0
-5%	'SOURCE_EXTERNE'	0,517	2.0
-10%	'SOURCE_EXTERNE'	0,553	6.0
-20%	'SOURCE_EXTERNE'	0,582	1.0

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

ε_{zz}	TYPE	GEFDYN	Tolerance (%)
-1%	'SOURCE_EXTERNE'	0,643	2.0

-2%	'SOURCE_EXTERNE'	0,755	1.0
-5%	'SOURCE_EXTERNE'	0,870	1.0
-10%	'SOURCE_EXTERNE'	0,926	1.0
-20%	'SOURCE_EXTERNE'	0,961	1.0

$\left(r_{ela}^{iso,m}+r_{iso}^{m}\right)$

ε_{zz}	TYPE	GEFDYN	Tolerance (%)
-1%	'SOURCE_EXTERNE'	0,146	1.0
-2%	'SOURCE_EXTERNE'	0,155	1.0
-5%	'SOURCE_EXTERNE'	0,166	1.0
-10%	'SOURCE_EXTERNE'	0,181	2.0
-20%	'SOURCE_EXTERNE'	0,214	1.0

2.3 Comments

The comparison enters the solutions *Code_Aster* and GEFDYN is particularly good, with generally less 1% of error. Relative errors higher than 1% appear for lower levels of values tested.

3 Summary of the results

One represents in the following curves the various comparisons enters *Code_Aster* and GEFDYN in terms of constraint σ_{yy} (Figure 1), of total voluminal deformation (Figure 2) and of coefficients of work hardening déviatoire (Figure 3) and isotropic (Figure 4).

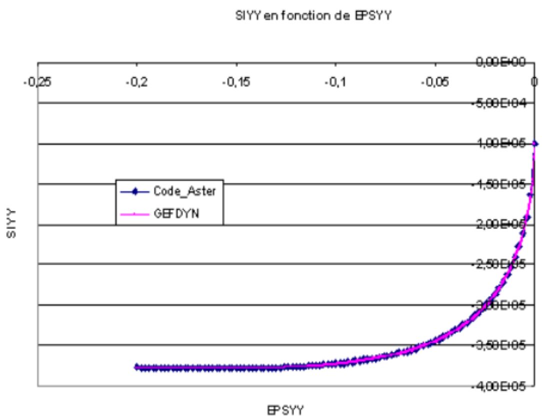


Figure **1** : σ_{yy} *according to the axial deformation: comparison enters the solutions Code_Aster and GEFDYN.*

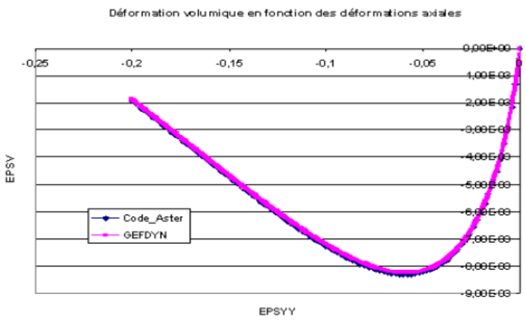


Figure **2** : *Total voluminal deformation according to the axial deformation: comparison enters the solutions Code_Aster and GEFDYN (noted "EPSv").*

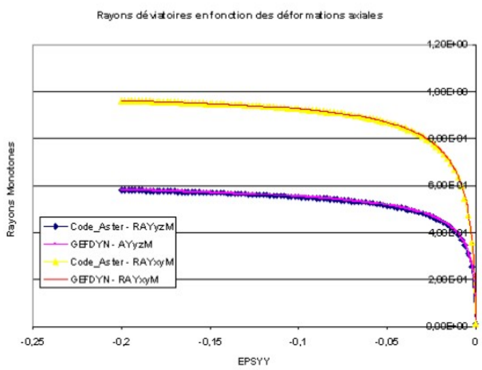


Figure **3** : *rays déviatoires according to the axial deformation: comparison enters the solutions Code_Aster ET GEFDYN.*

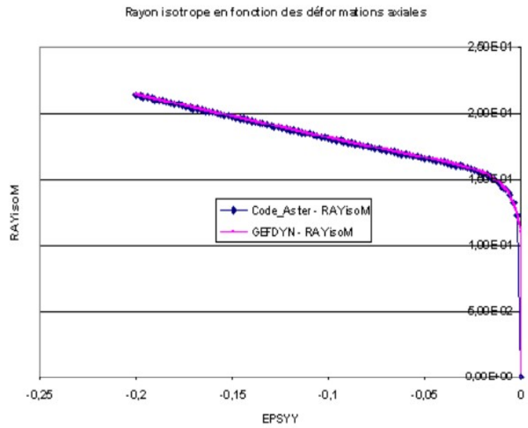


Figure **4** : *isotropic ray according to the axial deformation: comparison enters the solutions Code_Aster and GEFDYN.*