WTNV134 – Triaxial not drained cyclic with the law of Hujeux

Summary

This test makes it possible to validate the cyclic mechanism déviatoires installation of and the cyclic mechanism of consolidation of the law of Hujeux. It is about a cyclic triaxial compression test carried out in not drained condition. The hydraulic coupling is taken into account, the sample is completely saturated, the skeleton and the fluid is supposed to be incompressible.

The level of containment is of $30\,kPa$.

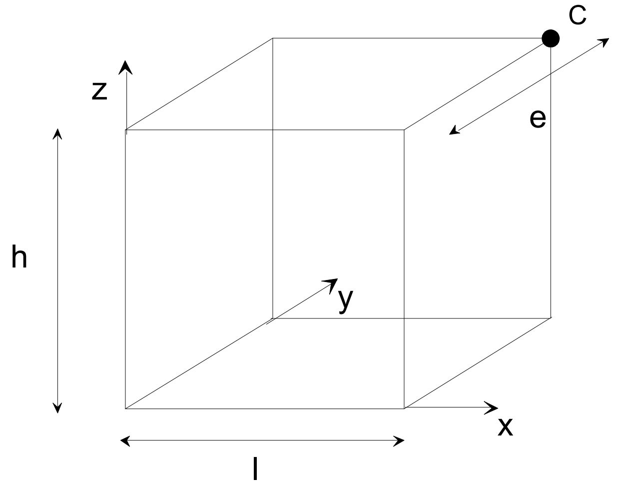
The results got with the law of Hujeux are compared with results resulting from the code finite elements GEFDYN Central School Paris (http://www.mssmat.ecp.fr/-GEFDYN,016-).

Modeling B makes it possible to deal with the same problem with a simulation of the type "not material", without finite element.

1 Problem of reference

1.1 Geometry

It is about a cubic sample of form of representation $1/8$ using an element HEXA20 .



hauteur : h = 1 m
largeur : l = 1 m
épaisseur : e = 1 m

1.2 Material properties

The elastic properties are:

- isotropic module of compressibility: $K=516200\,kPa$;
- modulus of rigidity: $\mu=238200\,kPa$;
- density [1] : $\rho_s=2500\,kg/m^3$.

The unelastic properties of the cyclic law of Hujeux result from the document referred with the following Internet address http://www.mssmat.ecp.fr/IMG/pdf/resp_loph40.pdf . They are the parameters relative to sand of Hostun:

- power of the non-linear elastic law: $n_e=0.4$;
- $\beta=24$;
- $d=2.5$;
- $b=0.2$;
- angle of friction: $\varphi=33°$;
- characteristic angle: $\psi=33°$;
- critical pressure: $P_{c0}=-1\,MPa$;
- pressure of reference: $P_{ref}=-1\,MPa$;
- elastic ray of the isotropic mechanisms: $r_{ela}^s=0.001$;
- elastic ray of the mechanisms déviatoires: $r_{ela}^d=0.005$;
- $a_{mon}=0.008$;
- $a_{cyc}=0.0001$;
- $c_{mon}=0.2$;
- $c_{cyc}=0.1$;
- $r_{hys}=0.05$;
- $r_{mob}=0.9$;
- $x_m=1$;
- $Dila=1$.

1 In the absence of gravity, the densities of the ground and water do not intervene in the problem.

The hydraulic properties are:

- coefficient of Biot: $B=1$;
- density of water: $\rho_e=1000\,kg/m^3$;
- viscosity: $\nu=0.001$;
- the intrinsic permeability: $K^{\text{int}}=1.\text{E}^{-8}\,m^3/kg/s$;
- the module of compressibility of water: $K_e=1.\text{E}^{+12}\,Pa$.

1.3 Boundary conditions and loadings

1.3.1 Boundary conditions

They is the conditions of symmetry on the element, which represents $1/8$ sample. Displacements are blocked on the front faces ($u_y=0$), side left ($u_x=0$) and lower ($u_z=0$).

1.3.2 Loading

Phase 1: consolidation of the sample until the confining pressure p $_0$
One brings the sample in a homogeneous state of stresses *effective* isostatic $\sigma_{xx}^0=\sigma_{yy}^0=\sigma_{zz}^0=\sigma^0=-30\,kPa$, by imposing the pressure σ_0 on the faces postpones, side right-hand side and higher of the element, while maintaining water pressures PRE1 worthless in the sample.

Phase 2: triaxial loading not drained
To obtain the not drained conditions, one forces on all the faces of worthless hydraulic flows.
While maintaining on the faces back and side right-hand side a pressure equalizes with σ_0 , one applies an alternative loading in pressure of amplitude $\Delta\sigma$ equalize with $15\,kPa$ on the higher face, in order to obtain a variation of the vertical constraint σ_{zz} in the sample understood in the interval $-45\,kPa\leq\sigma_{zz}\leq-15\,kPa$ (with the convention of minus sign for compression).

1.4 Results

The solutions post-are treated with the point C, in terms of effective isotropic pressure P ($=\text{tr}(\sigma')/3$), of plastic voluminal deformation ε_v^p and of isotropic coefficients of work hardening $\left(r_{iso}^m+r_{ela}^{iso}\right)$ and $\left(r_{iso}^c+r_{ela}^{iso}\right)$ and déviatoires $\left(r_d^m+r_{ela}^d\right)$ and $\left(r_d^c+r_{ela}^d\right)$.
The validation is carried out by comparison with the solutions GEFDYN provided by the Central School Paris.

2 Modeling A

2.1 Characteristics of modeling

Modeling is $3D$ with a hydro-mechanical coupling into quasi-static non-linear.
In phase 1 of loading, one brings the sample to the pressure of consolidation $\sigma^0_{xx}=\sigma^0_{yy}=\sigma^0_{zz}=\sigma^0=-30\,kPa$
One uses the law of Hujeux *cyclic*.

2.2 Characteristics of the grid

Many nodes: 20
Number of meshs and type: 1 HEXA20 and 6 QUAD8

2.3 Sizes tested and results

The solutions are calculated at the point C and compared with the results got with GEFDYN. They are given in terms of isotropic pressure, of plastic voluminal deformation ε^p_v and of factors of mobilization, and recapitulated in the following tables:

$3\cdot P'=\sigma_{ij}\cdot\delta_{ij}\ (kPa)$

$Q=\sigma_{zz}-\sigma_{xx}$ (kPa)	Code_Aster (kPa)	GEFDYN (kPa)	relative error
-15	-80,223	-80,194	0,038%
15	-73,988	-74,078	-0,122%
-15	-66,055	-66,250	-0,295%
15	-52,625	-52,999	-0,707%
-15	-45,539	-45,672	-0,292%

$\varepsilon^p_v=trace(\boldsymbol{\varepsilon}^p)$

$Q=\sigma_{zz}-\sigma_{xx}$ (kPa)	Code_Aster	GEFDYN	relative error
-15	-2.62e-5	-2.63e-5	-0,225%
$0\uparrow$	-2.80e-5	-2.78e-5	0,854%
$0\downarrow$	-4.48e-5	-4.43e-5	1,076%
$0\uparrow$	-7.11e-5	-7.05e-5	0,842%
$0\downarrow$	-1.13e-4	-1.11e-4	1,412%
$0\uparrow$	-1.85e-4	-1.85e-4	0,261%

$(r^c_{iso}+r^s_{ela})$

$Q=\sigma_{zz}-\sigma_{xx}$ (kPa)	Code_Aster	GEFDYN	relative error
$0\uparrow$	0.00140	0.00138	1,329%
$0\downarrow$	0.00220	0.00217	1,406%
$0\uparrow$	0.00341	0.00337	1,246%
$0\downarrow$	0.00518	0.00510	1,663%
$0\uparrow$	0.00195	0.00189	2,947%

$(r^m_{dev}+r^d_{ela})$

$Q=\sigma_{zz}-\sigma_{xx}$ (kPa)	Code_Aster	GEFDYN	relative error
15	0,326	0,326	-0,088%
-15	0,395	0,394	0,172%

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-15	0,579	0,578	0,255%

2.4 Remarks

The comparison enters the Code_Aster solutions and GEFDYN is relatively good. The differences are explained by the method of integration chosen for GEFDYN who is explicit. It would be necessary to increase the loading division to obtain values closer to those of Code_Aster.

3 Modeling B

3.1 Characteristics of modeling

Modeling is of type “not material” with linear relations on the components of the tensor of the deformations simulating the incompressibility, into quasi-static non-linear.
One considers here phase 2 of the loading, with a hydrostatic state of stresses initial $\sigma^0_{xx}=\sigma^0_{yy}=\sigma^0_{zz}=\sigma^0=-30\,kPa$
The data are identical to those of modeling A.

3.2 Characteristics of the grid

Pas d' finite element

3.3 Sizes tested and results

The solutions are calculated at the point C and compared with the results got with GEFDYN (same tests as modeling A). They are given in terms of isotropic pressure, of plastic voluminal deformation ε^p_v and of factors of mobilization, and recapitulated in the following tables:

$3\cdot P'=\sigma_{ij}\cdot\delta_{ij}\quad(kPa)$

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4 Summary of the results

One represents in the following curves the various comparisons enters *Code_Aster* and GEFDYN, in terms of isotropic pressure (Figure 4-a), of plastic voluminal deformation (Figure 4-b) and of coefficients of work hardening déviatoire (Figure 4-c).

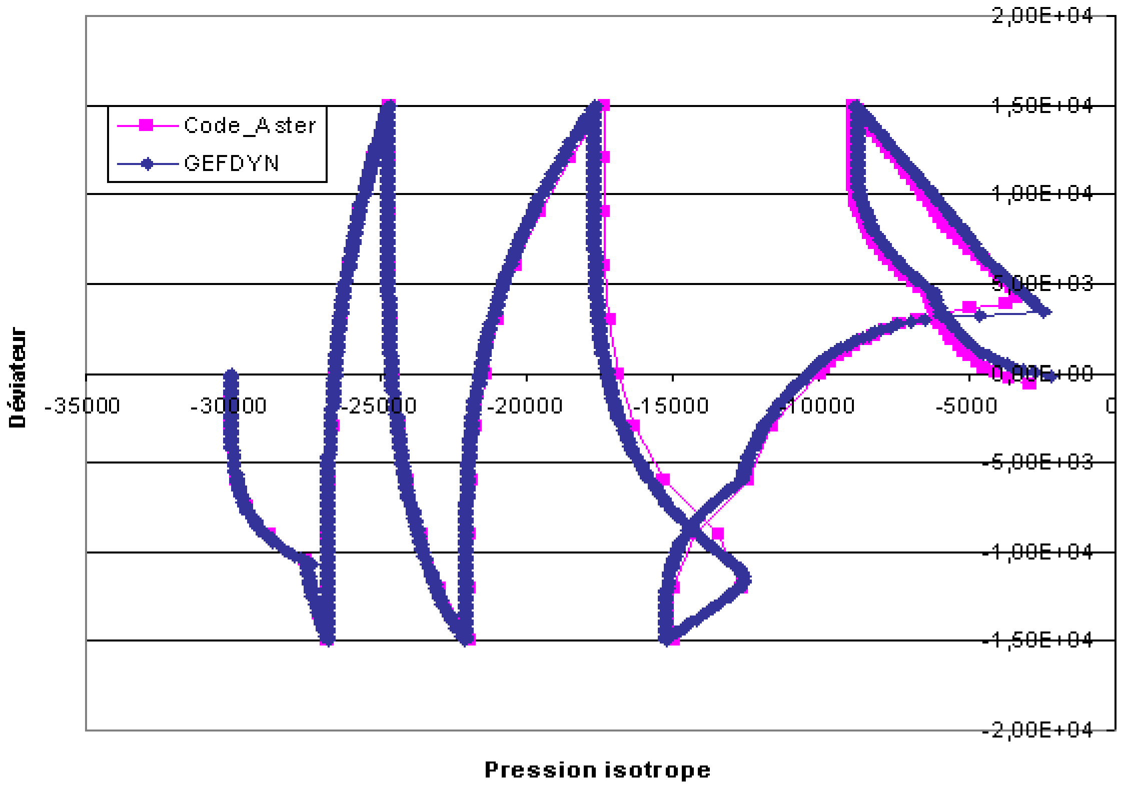

Figure 4-a : ***Cyclic triaxial compression test not drained (Plan $P-Q$): comparison enters the Code_Aster solutions and GEFDYN for a pressure of consolidation of $30\,kPa$.***

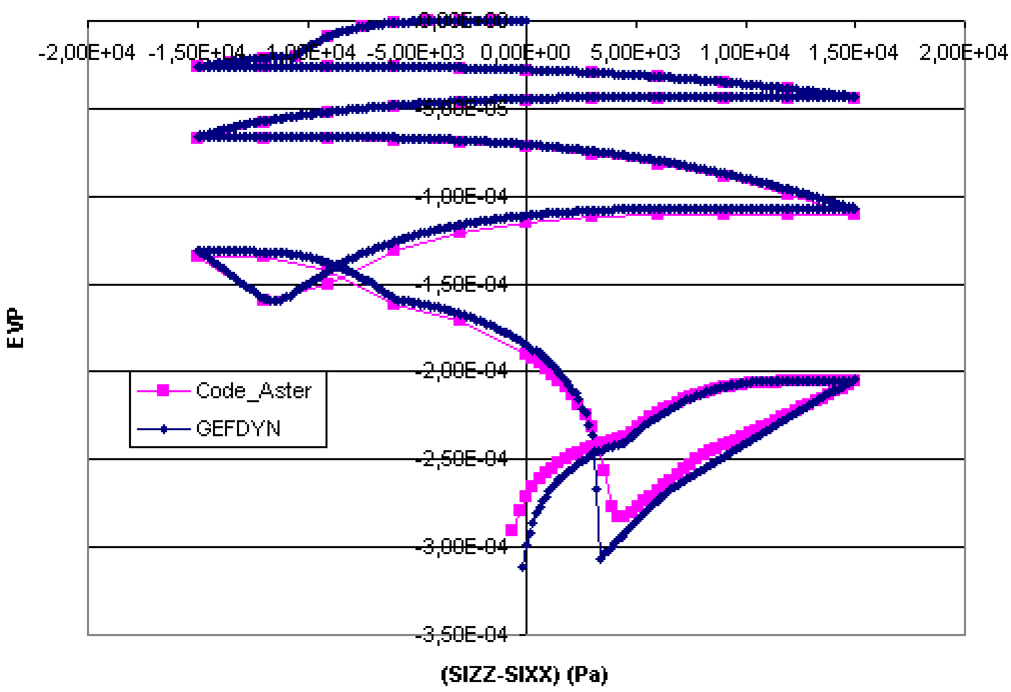

Figure 4-b: ***Plastic voluminal deformation according to the diverter of the constraints: comparison enters the Code_Aster solutions and*** GEFDYN **.**

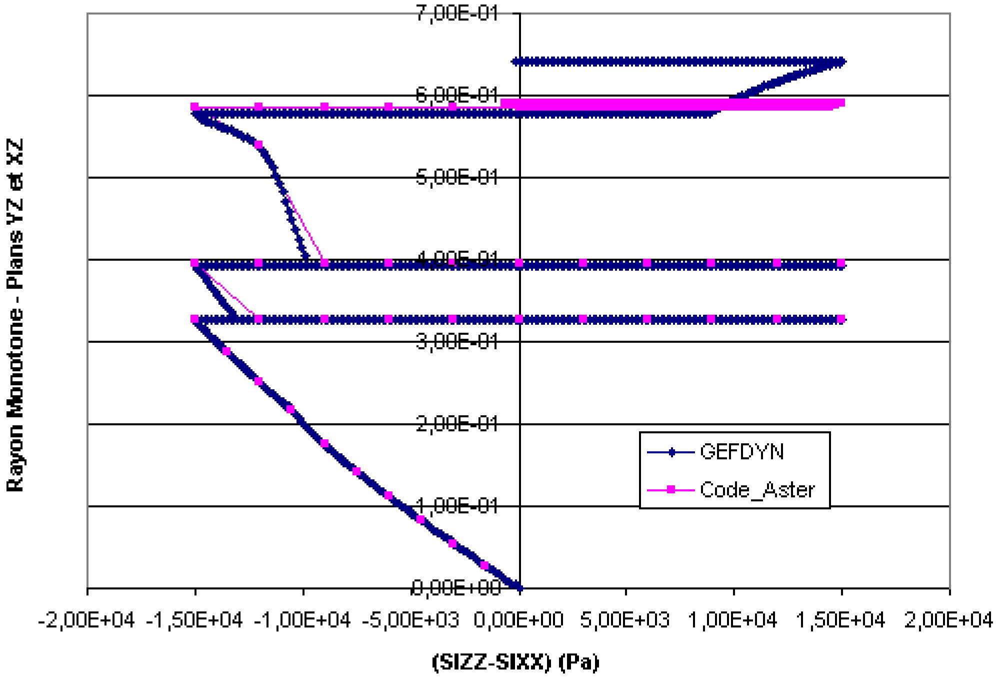

Figure 4-c: monotonous ray déviatoire according to the diverter of the constraints: comparison enters the results of Code_Aster and of GEFDYN.