WTNV133 – Triaxial not drained with the model of Hujeux

Summarized

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

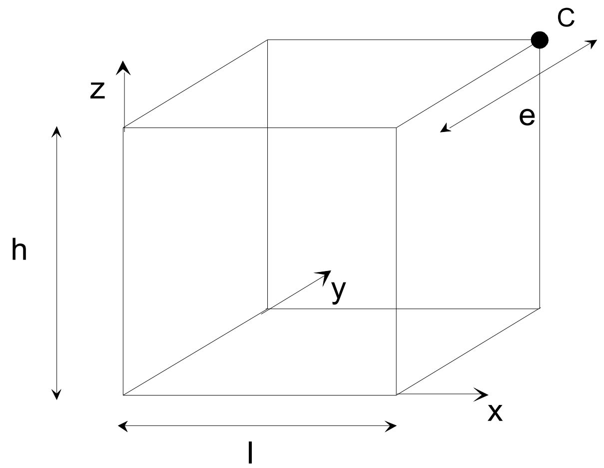
The levels of containment applied are of $50\,kPa$ and $200\,kPa$.

The results got with the model of Hujeux are compared with results resulting from the code finite elements GEFDYN of the Central School Paris.

1 Problem of reference

1.1 Geometry

It acts of a cubic sample of form of representation $1/8$ using an element $\mathrm{HEXA20}$.



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

1.2 Material properties

the elastic properties are:

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

The unelastic properties of the cyclic model of Hujeux are:

- power of the nonlinear elastic model: $n_e=0{,}4$;
- $\beta=24$;
- $d=2{,}5$;
- $b=0{,}2$;
- friction angle: $\varphi=33°$;
- angle of dilatancy: $\psi=33°$;
- critical pressure: $P_{c0}=-1\,MPa$;
- pressure of reference: $P_{ref}=-1\,MPa$;
- elastic radius of the isotropic mechanisms: $r^s_{éla}=0{,}001$;
- elastic radius of the mechanisms déviatoires: $r^d_{éla}=0{,}005$;
- $a_{mon}=0{,}008$;
- $a_{cyc}=0{,}0001$;
- $c_{mon}=0{,}2$;
- $c_{cyc}=0{,}1$;
- $r_{hys}=0{,}05$;
- $r_{mob}=0{,}9$;
- $x_m=1$;
- $dila=1$;

The hydraulic properties are:

1 the absence of gravity, the densities of the soil and water does not intervene in the problem.

- coefficient of Biot: $B=1$;
- density of water: $\rho_e=1000\,kg/m^3$;
- viscosity: $\nu=0{,}001$;
- the intrinsic permeability: $K^{\text{int}}=1\,E^{-8}m^3/kg/s$;
- the modulus of compressibility of water: $K_e=1\,E^{+12}Pa$ (coefficient of compressibility $1/K_e=1\,E^{-12}Pa^{-1}$)

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 sides ($u_y=0$), 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 statically determinate effective stress $\sigma_{xx}^0=\sigma_{yy}^0=\sigma_{zz}^0=\sigma_0$, by imposing the pressure σ_0 on the sides postpones, side right and higher of the element, and by maintaining everywhere water pressures $PRE1$ null.

Phase 2: triaxial loading not drained
to obtain the not drained conditions, one imposes on all the sides of null hydraulic flux.

While maintaining on the sides back and side right a pressure equalizes with σ_0 , one applies a loading in displacement of amplitude Δu equal to $0{,}02\,m$ the upper face, in order to obtain a homogeneous strain of the sample of 2% .

1.4 Results

the solutions post-are treated with the point C, in terms of equivalent stress of Von Mises Q ($=\sqrt{\frac{1}{2}(\sigma^d:\sigma^d)}$), effective isotropic pressure P ($=\frac{trace(\sigma')}{3}$), plastic voluminal strain ε_v^p and coefficients of hardening isotropic $(r_{iso}^m+r_{ela}^{iso,m})$ and $(r_{iso}^c+r_{ela}^{iso,c})$ déviatoire $(r_d^m+r_{ela}^{d,m})$.
The validation is carried out by comparison with solutions GEFDYN provided by the Central School Paris.

2 Modelization A

2.1 Characteristic of the modelization

The modelization is $3D$ with a hydro-mechanical coupling into quasi-static nonlinear.
In the phase 1 of loading, one brings the sample to the pressure of consolidation $\sigma_{xx}^0=\sigma_{yy}^0=\sigma_{zz}^0=\sigma_0=-50\,kPa$. This state of containment allows to regard the sample as dense *sand* .

The cyclic model of Hujeux *is used*.

2.2 Characteristics of the mesh

Many nodes: 20

Number of meshes and type: 1 $HEXA20$ and 6 $QUAD8$.

2.3 Quantities tested and results

the solutions are calculated at the point C and are compared with references GEFDYN. They are given in terms of isotropic pressure, plastic voluminal strain ε_v^p and factors of mobilization, and are recapitulated in the following tables :

$$Q=\sqrt{\frac{1}{2}\sigma_{ij}^d:\sigma_{ij}^d}\left(kPa\right)$$

ε_{zz}	Type of reference	GEFDYN (kPa)	tolerance (%)
-1.E-3	SOURCE_EXTERNE	3.154E+1	3.0
-2.E-3	SOURCE_EXTERNE	4.013E+1	2.0
-5.E-3	SOURCE_EXTERNE	5.194E+1	1.0
-1.E-2	SOURCE_EXTERNE	6.829E+1	1.0
-2.E-2	SOURCE_EXTERNE	1.032E+2	1.0

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

ε_{zz}	Type of reference	GEFDYN (kPa)	tolerance (%)
-1.E-3	SOURCE_EXTERNE	-1.389E+2	1.0
-2.E-3	SOURCE_EXTERNE	-1.338E+2	1.0
-5.E-3	SOURCE_EXTERNE	-1.250E+2	1.0
-1.E-2	SOURCE_EXTERNE	-1.368E+2	1.0
-2.E-2	SOURCE_EXTERNE	-1.860E+2	1.0

$$\varepsilon_v^p=trace\left(\varepsilon^p\right)$$

ε_{zz}	Type of reference	GEFDYN	tolerance (%)
-1.E-3	SOURCE_EXTERNE	-2.42E-5	6.0
-2.E-3	SOURCE_EXTERNE	-3.55E-5	4.0
-5.E-3	SOURCE_EXTERNE	-5.56E-5	3.0
-1.E-2	SOURCE_EXTERNE	-2.88E-5	5.0
-2.E-2	SOURCE_EXTERNE	7.437E-5	5.0

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

ε_{zz}	Type of reference	GEFDYN	tolerance (%)
-1.E-3	SOURCE_EXTERNE	0.02	1.0
-2.E-2	SOURCE_EXTERNE	0.0248	1.0

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

ε_{zz}	Type of reference	GEFDYN	tolerance (%)
-1.E-3	SOURCE_EXTERNE	1.49E-3	2.0
-2.E-3	SOURCE_EXTERNE	2.18E-3	2.0
-5.E-3	SOURCE_EXTERNE	3.36E-3	2.0
-1.E-2	SOURCE_EXTERNE	1.68E-3	3.0

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

ε_{zz}	Type of reference	GEFDYN	tolerance (%)
-1.E-3	SOURCE_EXTERNE	0.353	3.0
-2.E-3	SOURCE_EXTERNE	0.451	2.0
-5.E-3	SOURCE_EXTERNE	0.593	1.0
-1.E-2	SOURCE_EXTERNE	0.699	1.0
-2.E-2	SOURCE_EXTERNE	0.794	1.0

2.4 Remarks

the comparison between solutions *Code_Aster* and GEFDYN is relatively good, with generally less 1% of error. The relative errors higher than 1% appear for levels of values tested relatively low and close to the numerical accuracy applied during computation.

3 Modelization B

3.1 Characteristic of the modelization

The modelization is 3D with a hydro-mechanical coupling into quasi-static nonlinear.
In the phase 1 of loading, one brings the sample to the pressure of consolidation $\sigma_{xx}^{0}=\sigma_{yy}^{0}=\sigma_{zz}^{0}=\sigma_{0}=-200\,kPa$. This state of containment allows to regard the sample as fairly *dense sand*.
The cyclic model of Hujeux *is used*.

3.2 Characteristics of the mesh

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

3.3 Quantities tested and results

the solutions are calculated at the point C and are compared with references GEFDYN. They are given in terms of isotropic pressure, plastic voluminal strain ε_{v}^{p} and factors of mobilization, and are recapitulated in the following tables:

$$Q=\sqrt{\frac{1}{2}\sigma_{ij}^{d}:\sigma_{ij}^{d}}(kPa)$$

ε_{zz}	Type of reference	GEFDYN (kPa)	tolerance (%)
-1.E-3	SOURCE_EXTERNE	1.015E+2	3.0
-2.E-3	SOURCE_EXTERNE	1.343E+2	2.0
-5.E-3	SOURCE_EXTERNE	1.808E+2	1.0
-1.E-2	SOURCE_EXTERNE	2.139E+2	1.0
-2.E-2	SOURCE_EXTERNE	2.495E+2	1.0

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

ε_{zz}	Type of reference	GEFDYN (kPa)	tolerance (%)
-1.E-3	SOURCE_EXTERNE	-5.889E+2	1.0
-2.E-3	SOURCE_EXTERNE	-5.823E+2	1.0
-5.E-3	SOURCE_EXTERNE	-5.638E+2	1.0
-1.E-2	SOURCE_EXTERNE	-5.439E+2	1.0
-2.E-2	SOURCE_EXTERNE	-5.442E+2	1.0

$$\varepsilon_{v}^{p}=trace(\varepsilon^{p})$$

ε_{zz}	Type of reference	GEFDYN	tolerance (%)
-1.E-3	SOURCE_EXTERNE	-1.37E-5	8.0
-2.E-3	SOURCE_EXTERNE	-2.19E-5	6.0
-5.E-3	SOURCE_EXTERNE	-4.51E-5	3.0
-1.E-2	SOURCE_EXTERNE	-7.03E-5	2.0
-2.E-2	SOURCE_EXTERNE	-7.00E-5	2.0

$$(r_{iso}^{c}+r_{ela}^{s,c})$$

ε_{zz}	Type of reference	GEFDYN	tolerance (%)

-1.E-3	SOURCE_EXTERNE	1.51E-3	1.0
-2.E-3	SOURCE_EXTERNE	2.40E-3	1.0
-5.E-3	SOURCE_EXTERNE	4.91E-3	1.0
-1.E-2	SOURCE_EXTERNE	7.60E-3	1.0
-2.E-2	SOURCE_EXTERNE	1.16E-3	2.0

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

ε_{zz}	Type of reference	GEFDYN	tolerance (%)
-1.E-3	SOURCE_EXTERNE	0.334	3.0
-2.E-3	SOURCE_EXTERNE	0.436	2.0
-5.E-3	SOURCE_EXTERNE	0.583	1.0
-1.E-2	SOURCE_EXTERNE	0.693	1.0
-2.E-2	SOURCE_EXTERNE	0.790	1.0

3.4 Remarks

the comparison between solutions *Code_Aster* and GEFDYN is relatively good, with generally less 1% of error. The relative errors higher than 1% appear for levels of values tested relatively low and close to the numerical accuracy applied during computation.

4 Modelization C

4.1 Characteristic of the modelization

The modelization is $3D$ under-integrated (`3D_HM_SI`) with a hydro-mechanical coupling into quasi-static nonlinear.
In the phase 1 loading, one brings the sample to the pressure of consolidation $\sigma_{xx}^0=\sigma_{yy}^0=\sigma_{zz}^0=\sigma_0=-50\,kPa$. This state of containment allows to regard the sample as dense *sand* .

The cyclic model of Hujeux *is used*.

4.2 Characteristics of the mesh

Many nodes: 20

Number of meshes and type: 1 $HEXA20$ and 6 $QUAD8$.

4.3 Quantities tested and results

the solutions are calculated at the point C and compared with references GEFDYN. They are given in terms of isotropic pressure, of plastic voluminal strain ε_v^p and factors of mobilization, and recapitulated in the following tables :

$$Q=\sqrt{\frac{1}{2}\sigma_{ij}^d:\sigma_{ij}^d}(kPa)$$

ε_{zz}	formula of reference	GEFDYN (kPa)	tolerance (%)
-1.E-3	SOURCE_EXTERNE	3.154E+1	3.0
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$$3\ .\ P'=\sigma_{ij}\cdot\delta_{ij}(kPa)$$

ε_{zz}	Standard reference	GEFDYN (kPa)	tolerance (%)
-1.E-3	SOURCE_EXTERNE	-1.389E+2	1.0
-2.E-3	SOURCE_EXTERNE	-1.338E+2	1.0
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$$\varepsilon_v^p=trace(\varepsilon^p)$$

ε_{zz}	Standard reference	GEFDYN	tolerance (%)
-1.E-3	SOURCE_EXTERNE	-2.42E-5	6.0
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$\left(r_{iso}^{m}+r_{ela}^{s,m}\right)$

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4.4 Remarks

the comparison between the solutions *Code_Aster* and GEFDYN is relatively good, with generally less 1% of error. The relative errors higher than 1% appear for levels of values tested relatively low and close to the numerical accuracy applied during computation.

5 Summary of the results

One represents in the following curves the various comparisons between *Code_Aster* and Lawyer (calculation programme of constitutive law, not finite elements), in terms of isotropic pressure (Figure 5-a), of plastic voluminal strain (Figure 5-b) and of coefficients of monotonous and cyclic isotropic hardening (figures 5-c and 5-d).

The differences noted between the two modelizations for the values of the cyclic factors of mobilization are due to a management different in time from the kinematical variables. Their values are only different when the cyclic mechanisms are not active.

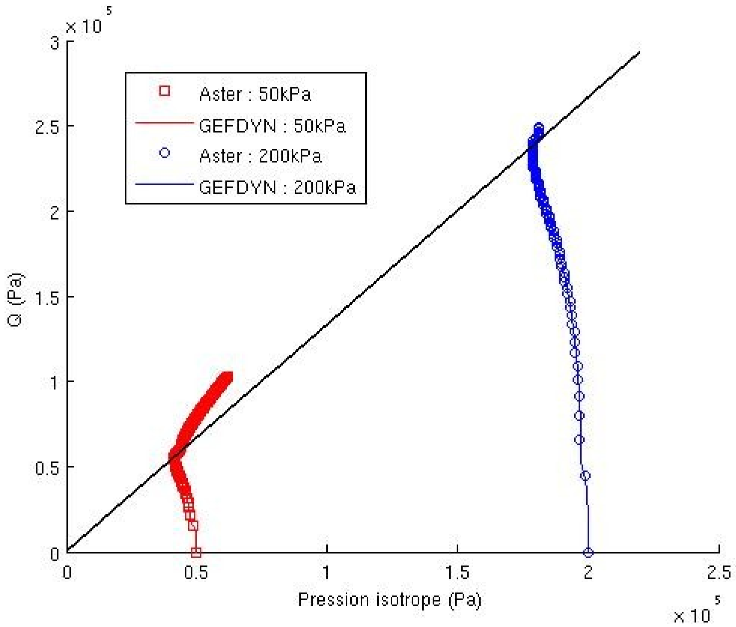
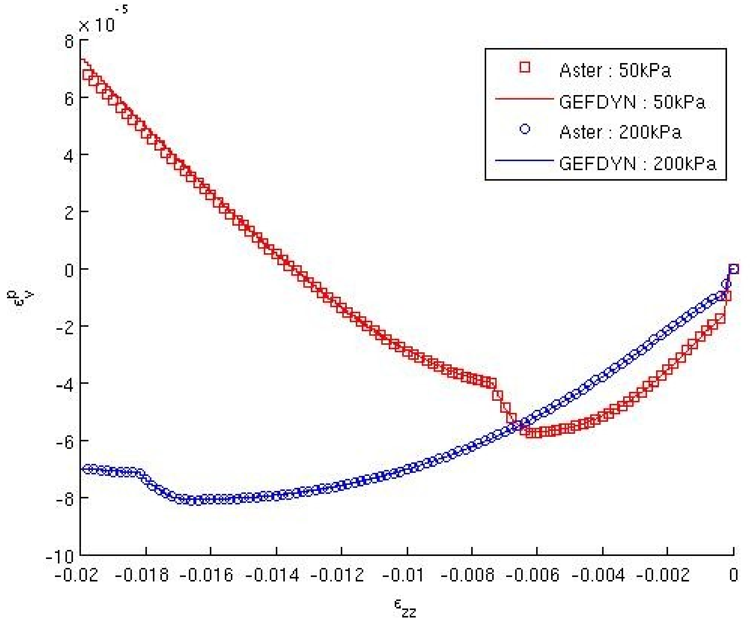
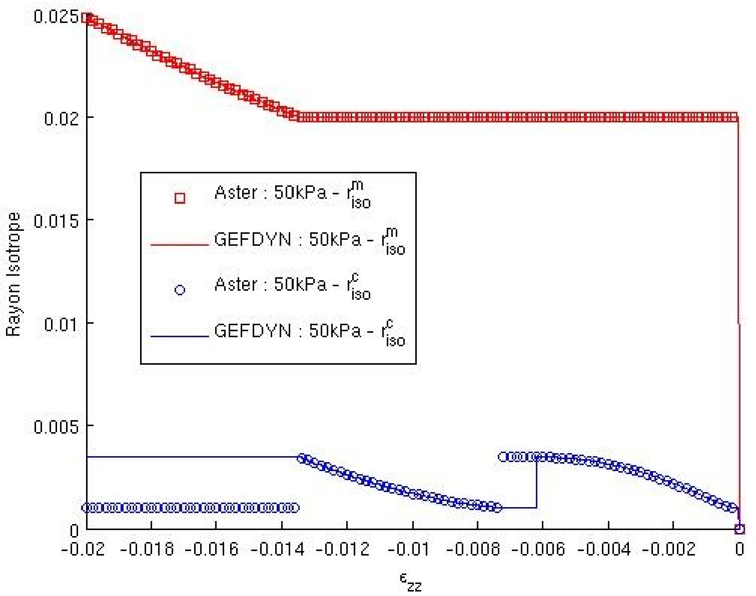


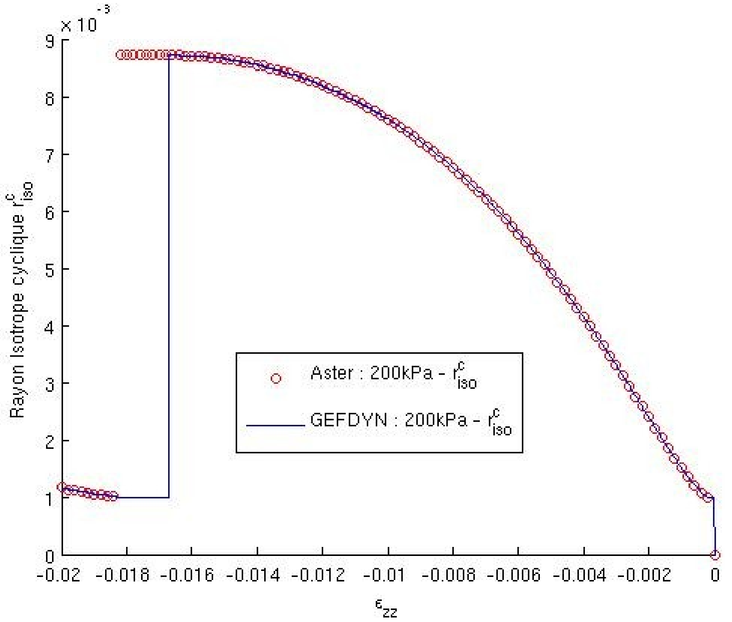
Figure 5-a : 5-a *Cyclic triaxial compression test not drained (Plane $P-Q$): comparison enters the solutions Code_Aster and Lawyer for the pressures of consolidation of $50\,kPa$ and $200\,kPa$.*



Appear 5-b : Plastic voluminal strain according to the vertical strains for the two levels of compression with $50\,kPa$ and $200\,kPa$: comparison enters the solutions Code_Aster and Lawyer .



Appear 5-c : radius isotropic monotonous and cyclic according to the vertical strains for the level of consolidation of $50\,kPa$: comparison enters the results Code_Aster and Lawyer.



Appear 5-d : cyclic isotropic radius according to the vertical strains for the level of consolidation of $200\,kPa$: comparison enters the results Code_Aster and Lawyer.