COMP012 – Test of the law of Hujeux on a material point

Summary:

The objective of this test is to validate the macro-order **CALC_ESSAI_GEOMECA** [U4.90.21] which makes it possible to simulate at the material point eight types of ways of loading characteristic of tests géomechanics:

- drained monotonous triaxial compression test
- monotonous triaxial compression test not drained
- cyclic triaxial compression test not drained
- alternate cyclic triaxial compression test drained
- cyclic triaxial compression test nonalternate drained
- drained cyclic shear test
- drained cyclic test oedometric
- test of isotropic compression cyclic drained

These eights tests are simulated with the law of Hujeux. They are gathered in modeling **With**. The calculated solutions are compared with results resulting from the code finite elements GEFDYN of the Central School Paris for the first three tests, one carries out a test of nonregression for the five last and one compares the solution calculated with **ESSAI_ISOT_C** with the results of the case test ssnv204a.

The ninth test is triaxial monotonous drained simulated with the law of Mohr-Coulomb. It is the object of modeling **B**. The solution is compared with an analytical solution.

Modeling **C** draft the not-drained cyclic triaxial compression test of a sand modelled with the law of Hujeux. It makes it possible to validate the detection of specific instability to this test and the swing of the test in controlled deformation.

A cyclic shear test drained with the law of Iwan is tested in modeling **D**.

1 Problem of reference for modeling A

1.1 Geometry

The geometry is $0D$ (modeling is of type “not material”).

1.2 Properties of material

The material is of the type of a dense sand. The elastic properties are:

- isotropic module of compressibility: $K=516200\,kPa$
- modulus of rigidity: $\mu=238200\,kPa$

The unelastic properties (Hujeux) are:

- power of the non-linear elastic law: $n_e=0.4$
- $\beta=24$
- $d=2.5$
- $b=0.2$
- angle of friction: $\varphi=33°$
- angle of dilatancy: $\psi=33°$
- critical pressure: $P_{c0}=-1000\,kPa$
- pressure of reference: $P_{ref}=-1000\,kPa$
- elastic ray of the isotropic mechanism: $r^s_{éla}=0.001$
- elastic ray of the mechanism déviatoire: $r^d_{éla}=0.005$
- $a_{mon}=0.0001$
- $a_{cyc}=0.008$
- $c_{mon}=0.2$
- $c_{cyc}=0.1$
- $r_{hys}=0.05$
- $r_{mob}=0.9$
- $x_m=1$
- $\mathrm{dila}=1$

The hydraulic properties are:

- coefficient of Biot: $B=1.$
- module of compressibility of water $K_e=1.\mathrm{E}12\,Pa$ (coefficient of compressibility $1/K_e=1.\mathrm{E}-12\,Pa^{-1}$)

1.3 Boundary conditions and loadings

Six ways of loading characteristic of tests géomechanics are automatically defined by the macro-order **CALC_ESSAI_GEOMECA** [U4.90.21].

1.3.1 Way of loading 1

This way is characteristic of a drained monotonous triaxial compression test:

- one starts from a hydrostatic state of stress: $\sigma^0_{xx}=\sigma^0_{yy}=\sigma^0_{zz}=\sigma^0=-5.\mathrm{E}4\,Pa$, and of a state of worthless deformations.
- one keeps then the side pressure: $\sigma_{xx}=\sigma_{yy}=-5.\mathrm{E}4\,Pa$, while imposing a slope of vertical deformation (Figure 1.3.1-1) enter $t=0$ and $t=100$, of end value $\varepsilon_{zz}=-20\%$

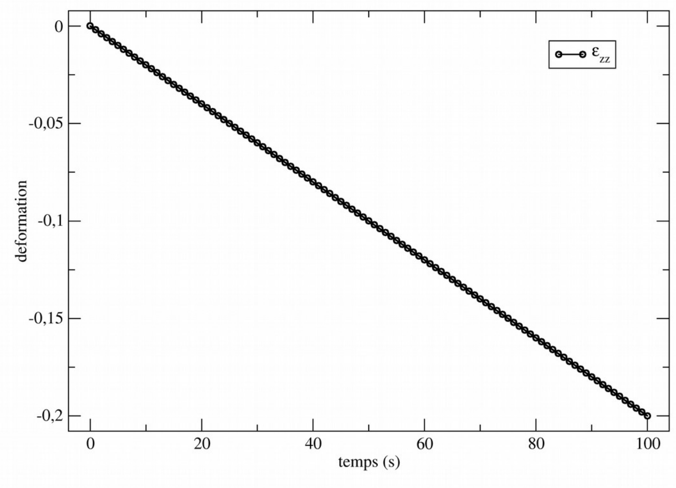

Figure 1.3.1-1: Way of loading 1

Under the keyword factor **ESSAI_TD** macro-order **CALC_ESSAI_GEOMECA** [U4.90.21], this way corresponds to the following seizure:

- PRES_CONF $=-5.\mathrm{E}4\,Pa$
- EPSI_IMPOSE $=-0.2$

1.3.2 Way of loading 2

This way is characteristic of a monotonous triaxial compression test not drained (one supposes total saturation):

- one starts from a hydrostatic state of stress: $\sigma_{xx}^0=\sigma_{yy}^0=\sigma_{zz}^0=\sigma^0=-5.\mathrm{E}4\,Pa$, and of a state of worthless deformations.
- one keeps then the side pressure: $\sigma_{xx}=\sigma_{yy}=-5.\mathrm{E}4\,Pa$, while imposing a slope of vertical deformation enters $t=0$ and $t=100$, of end value $\varepsilon_{zz}=-2\%$. The skeleton and the fluid are supposed to be incompressible, which one models while imposing $tr(\boldsymbol{\varepsilon})=0$. For that one imposes on the lateral distortions ε_{xx} and ε_{yy} to follow a slope such as enters $t=0$ and $t=100$, these deformations vary 0 with 1% (Figure 1.3.2-1).

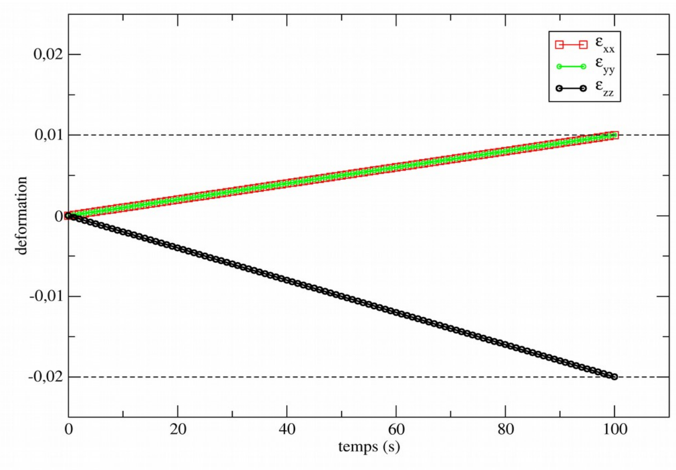

Figure 1.3.2-1: Way of loading 2

Under the keyword factor **ESSAI_TND** macro-order **CALC_ESSAI_GEOMECA** [U4.90.21], this way corresponds to the following seizure:

- $\text{PRES\_CONF} = -5.\text{E}4\ Pa$
- $\text{EPSI\_IMPOSE} = -0.02$

1.3.3 Way of loading 3

This way is characteristic of a cyclic triaxial compression test not drained (one supposes total saturation):

- one starts from a hydrostatic state of stress: $\sigma^0_{xx} = \sigma^0_{yy} = \sigma^0_{zz} = \sigma^0 = -3.\text{E}4\ Pa$, and of a state of worthless deformations.
- one keeps then the side pressure: $\sigma_{xx} = \sigma_{yy} = -3.\text{E}4\ Pa$, while imposing for the vertical effective constraint σ'_{zz} the cyclic loading illustrated with the Figure 1.3.3-1, of amplitude $1.5\text{E}4\ Pa$ and of median value $-3.\text{E}4\ Pa$. This is modelled by imposing linear relations between the diagonal components of the tensor of the deformations, so that:

$$\begin{cases} \sigma_{xx} + K_e tr(\boldsymbol{\varepsilon}) = \sigma^0 \\ \sigma_{yy} + K_e tr(\boldsymbol{\varepsilon}) = \sigma^0 \\ \sigma_{zz} + K_e tr(\boldsymbol{\varepsilon}) = \sigma'_{zz} \end{cases}$$

where K_e indicate the module of compressibility of water, σ^0 kept side pressure constant, and σ'_{zz} the imposed effective constraint (Figure 1.3.3-1)

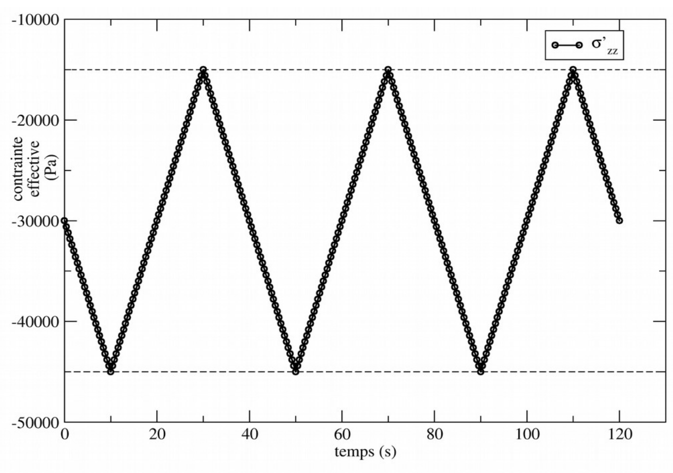

Figure 1.3.3-1: Way of loading 3

Under the keyword factor **ESSAI_TND_C** macro-order **CALC_ESSAI_GEOMECA** [U4.90.21], this way of loading corresponds to the following seizure:

- $\text{PRES\_CONF} = -3.\text{E}4\ Pa$
- $\text{SIGM\_IMPOSE} = 1.5\text{E}4\ Pa$
- $\text{NB\_CYCLE} = 3$

1.3.4 Way of loading 4

This way is characteristic of an alternate cyclic triaxial compression test drained:

- one starts from a hydrostatic state of stress: $\sigma^0_{xx} = \sigma^0_{yy} = \sigma^0_{zz} = \sigma^0 = -5.\text{E}4\ Pa$, and of a state of worthless deformations.
- one keeps then the side pressure: $\sigma_{xx} = \sigma_{yy} = -5.\text{E}4\ Pa$, while imposing for ε_{zz} the cyclic loading illustrated with the Figure 1.3.4-1, of amplitude 2% and of median value 0.

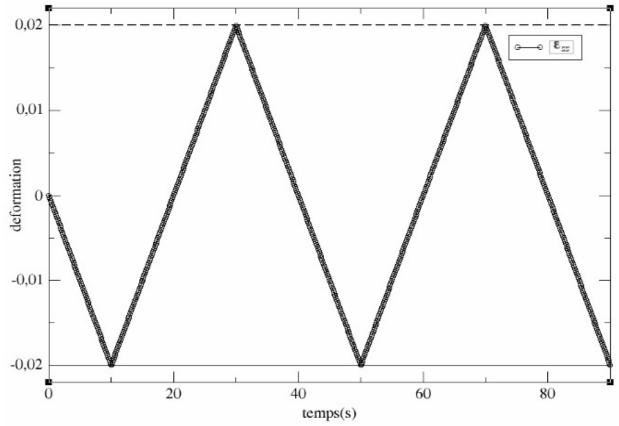

Figure 1.3.4-1: Way of loading 4

Under the keyword factor **ESSAI_TD_A** macro-order **CALC_ESSAI_GEOMECA** [U4.90.21], this way corresponds to the following seizure:

- PRES_CONF $= -5.E4\,Pa$
- EPSI_IMPOSE $= 0.02$
- NB_CYCLE $= 2$

1.3.5 Way of loading 5

This way is characteristic of a cyclic triaxial compression test nonalternate drained:

- one starts from a hydrostatic state of stress: $\sigma_{xx}^0 = \sigma_{yy}^0 = \sigma_{zz}^0 = \sigma^0 = -5.E4\,Pa$, and of a state of worthless deformations.
- one keeps then the side pressure: $\sigma_{xx} = \sigma_{yy} = -5.E4\,Pa$, while imposing for ε_{zz} the cyclic loading illustrated with the Figure 1.3.5-1, of amplitude 2% and of median value $\varepsilon_{zz} = -1\%$.

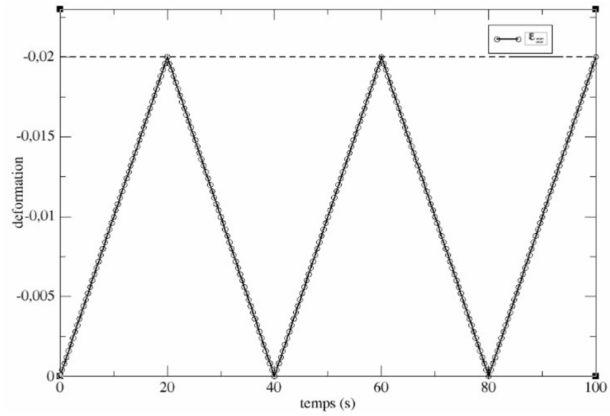

Figure 1.3.5-1: Way of loading 5

Under the keyword factor **ESSAI_TD_NA** macro-order **CALC_ESSAI_GEOMECA** [U4.90.21], this way corresponds to the following seizure:

- PRES_CONF $= -5.E4\,Pa$
- EPSI_IMPOSE $= -0.02$
- NB_CYCLE $= 2$

1.3.6 Way of loading 6

This way is characteristic of a drained cyclic shear test:

- one starts from a hydrostatic state of stress: $\sigma_{xx}^0=\sigma_{yy}^0=\sigma_{zz}^0=\sigma^0=-5.E4\,Pa$, and of a state of worthless deformations.
- one keeps then the side pressure: $\sigma_{xx}=\sigma_{yy}=-5.E4\,Pa$, while imposing for γ_{xy} the cyclic loading illustrated with the Figure 1.3.6-1, of amplitude 0.039% and of median value 0.

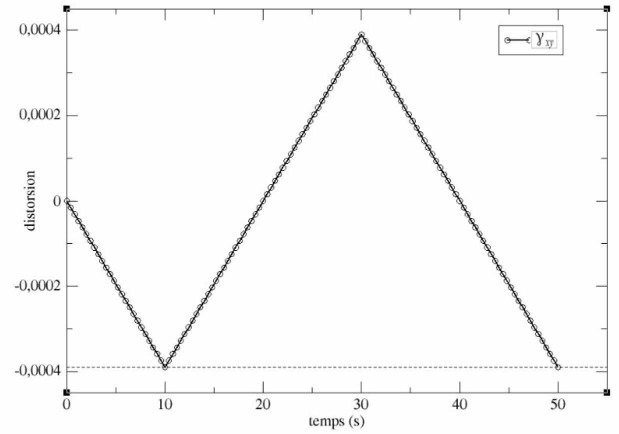

Figure 1.3.6-1: Way of loading 6

Under the keyword factor **ESSAI_CISA_C** macro-order **CALC_ESSAI_GEOMECA** [U4.90.21], this way corresponds to the following seizure:

- PRES_CONF$=-5.E4\,Pa$
- GAMMA_IMPOSE$=3.9E-4$
- NB_CYCLE$=1$

1.3.7 Way of loading 7

This way is characteristic of a drained cyclic test oedometric:

- one starts from a hydrostatic state of stress: $\sigma_{xx}^0=\sigma_{yy}^0=\sigma_{zz}^0=\sigma^0=-5.E4\,Pa$, and of a state of worthless deformations.
- one keeps then the side pressure: $\sigma_{xx}=\sigma_{yy}=-5.E4\,Pa$, while imposing for the vertical effective constraint σ'_{zz} the cyclic loading illustrated with the Figure 1.3.7-1, of variable amplitude equalizes respectively with $-3.E4\,Pa$, $-4.E4\,Pa$ and $-5.E4\,Pa$, counted starting from the initial hydrosratic constraint for the first cycle, and starting from the constraint of discharge for the following cycles. The constraint of discharge is of: $-6E4\,Pa$.

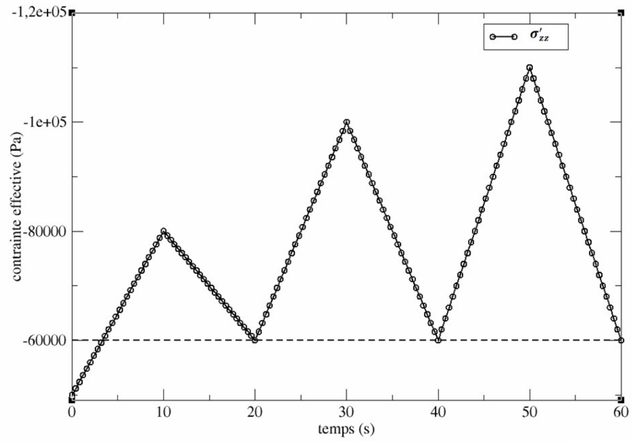

Figure 1.3.7-1 : Way of loading 7

Under the keyword factor **ESSAI_OEDO_C** macro-order **CALC_ESSAI_GEOMECA** [U4.90.21], this way corresponds to the following seizure:

- $\text{PRES\_CONF}=-5.\text{E4}\,Pa$
- $\text{SIGM\_IMPOSE}=(-3.\text{E4},-4.\text{E4},-5.\text{E4},)$
- $\text{SIGM\_DECH}=-6.\text{E4}$

1.3.8 Way of loading 8

This way is characteristic of a drained test of isotropic compression cyclic:

- one starts from a hydrostatic state of stress: $\sigma^0_{xx}=\sigma^0_{yy}=\sigma^0_{zz}=\sigma^0=-1.\text{E5}\,Pa$, and of a state of worthless deformations.
- one applies then an isotropic pressure $\sigma'_{xx}=\sigma'_{yy}=\sigma'_{zz}=\sigma'_c$, of which the amplitude with each cycle is equal respectively to $-2.\text{E5}\,Pa$ and $-2.4\text{E5}\,Pa$, counted starting from the initial hydrostatic constraint for the first cycle, and starting from the constraint of discharge for the second. The constraint of discharge being equal to the initial isotropic constraint: $-1\text{E5}\,Pa$. This loading is illustrated with the Figure 1.3.8-1.

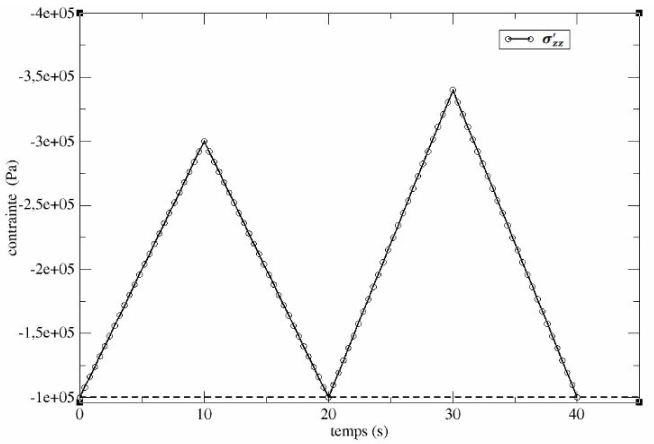

Figure 1.3.8-1 : Way of loading 8

Under the keyword factor **ESSAI_ISOT_C** macro-order **CALC_ESSAI_GEOMECA** [U4.90.21], this way corresponds to the following seizure:

- $\text{PRES\_CONF}=-1.\text{E5}\,Pa$
- $\text{SIGM\_IMPOSE}=(-2.\text{E5},-2.4\text{E5})$
- $\text{SIGM\_DECH}=-1.\text{E5}$

2 Modeling A

2.1 Characteristics of modeling

Simulation at the material point.

2.2 Sizes tested and results

2.2.1 Way of loading 1 (ESSAI_TD)

The solutions post-are treated in the single point of the model and are compared with references GEFDYN. in terms of equivalent constraint of Von Mises Q and of voluminal deformation ε_v

$$Q=\sqrt{\frac{3}{2}\boldsymbol{\sigma}^d:\boldsymbol{\sigma}^d}$$

Identification	Type of reference	Value of reference	Tolerance
$\varepsilon_{zz}=-1\%$	'SOURCE_EXTERNE'	117640 Pa	2.%
$\varepsilon_{zz}=-2\%$	'SOURCE_EXTERNE'	157072 Pa	2.%
$\varepsilon_{zz}=-5\%$	'SOURCE_EXTERNE'	200850 Pa	1.%
$\varepsilon_{zz}=-10\%$	'SOURCE_EXTERNE'	207649 Pa	1.%
$\varepsilon_{zz}=-20\%$	'SOURCE_EXTERNE'	185854 Pa	1.%

$$\varepsilon_v=tr(\boldsymbol{\varepsilon})$$

Identification	Type of reference	Value of reference	Tolerance
$\varepsilon_{zz}=-1\%$	'SOURCE_EXTERNE'	-0,382%	2.%
$\varepsilon_{zz}=-2\%$	'SOURCE_EXTERNE'	-0,434	2.%
$\varepsilon_{zz}=-10\%$	'SOURCE_EXTERNE'	1.07%	3.%
$\varepsilon_{zz}=-20\%$	'SOURCE_EXTERNE'	3,191%	5.%

2.2.2 Way of loading 2 (ESSAI_TND)

The solutions post-are treated in the single point of the model and are compared with references GEFDYN. in terms of equivalent constraint of Von Mises Q and of isotropic pressure P .

$$Q=\sqrt{\frac{3}{2}\boldsymbol{\sigma}^d:\boldsymbol{\sigma}^d}$$

Identification	Type of reference	Value of reference	Tolerance
$\varepsilon_{zz}=-0.1\%$	'SOURCE_EXTERNE'	31547 Pa	3.%
$\varepsilon_{zz}=-0.2\%$	'SOURCE_EXTERNE'	40129 Pa	2.%
$\varepsilon_{zz}=-0.5\%$	'SOURCE_EXTERNE'	51937 Pa	1.%
$\varepsilon_{zz}=-1.\%$	'SOURCE_EXTERNE'	68286 Pa	1.%

$\varepsilon_{zz}=-2.\%$	'SOURCE_EXTERNE'	1103161 Pa	1.%

$$3P=tr(\boldsymbol{\sigma})$$

Identification	Type of reference	Value of reference	Tolerance
$\varepsilon_{zz}=-0.1\%$	'SOURCE_EXTERNE'	-138887 Pa	1.%
$\varepsilon_{zz}=-0.2\%$	'SOURCE_EXTERNE'	-133789 Pa	1.%
$\varepsilon_{zz}=-0.5\%$	'SOURCE_EXTERNE'	-124952 Pa	1.%
$\varepsilon_{zz}=-1.\%$	'SOURCE_EXTERNE'	-136801 Pa	1.%
$\varepsilon_{zz}=-2.\%$	'SOURCE_EXTERNE'	-185971 Pa	1.%

2.2.3 Way of loading 3 (ESSAI_TND_C)

The solutions post-are treated in the single point of the model and are compared with references GEFDYN. in terms of isotropic pressure P

$$3P=tr(\boldsymbol{\sigma})$$

Identification	Type of reference	Value of reference	Tolerance
$t=10.s$	'SOURCE_EXTERNE'	-80193. Pa	1.%
$t=30.s$	'SOURCE_EXTERNE'	-74078. Pa	1.%
$t=50.s$	'SOURCE_EXTERNE'	-66250. Pa	1.%
$t=70.s$	'SOURCE_EXTERNE'	-52999 Pa	2.%
$t=90.s$	'SOURCE_EXTERNE'	-45672. Pa	2.%

2.2.4 Way of loading 4 (ESSAI_TD_A)

One carries out a test of nonregression on the equivalent constraint of Von Mises Q and of voluminal deformation ε_{vol} .

$$Q=\sqrt{\frac{3}{2}\boldsymbol{\sigma}^d:\boldsymbol{\sigma}^d}$$

Identification	Type of reference	Value of reference	Tolerance
$t=10.s$	'NON_REGRESSION'	-15.57654 E+04 Pa	0.0001%
$t=30.s$	'NON_REGRESSION'	4.24744 E+04 Pa	0.0001%
$t=50.s$	'NON_REGRESSION'	-15.39714 E+04 Pa	0.0001%

$$\epsilon_{vol}$$

Identification	Type of reference	Value of reference	Tolerance
$t=10.s$	'NON_REGRESSION'	-4.33281931383E-03	0.0001%
$t=30.s$	'NON_REGRESSION'	5.89630135815E-04	0.0001%
$t=50.s$	'NON_REGRESSION'	-8.75197203863E-03	0.0001%

2.2.5 Way of loading 5 (ESSAI_TD_NA)

One carries out a test of nonregression on the equivalent constraint of Von Mises Q and of voluminal deformation ε_{vol}.

$$Q=\sqrt{\frac{3}{2}\boldsymbol{\sigma}^d:\boldsymbol{\sigma}^d}$$

Identification	Type of reference	Value of reference	Tolerance
$t=20.s$	'NON_REGRESSION'	-15.58495 E+04 Pa	0.0001%
$t=40.s$	'NON_REGRESSION'	3.66029 E+04 Pa	0.0001%
$t=60.s$	'NON_REGRESSION'	-14.29862 E+04 Pa	0.0001%

ϵ_{vol}

Identification	Type of reference	Value of reference	Tolerance
$t=20.s$	'NON_REGRESSION'	-4.33090139425 E-3	0.0001%
$t=40.s$	'NON_REGRESSION'	-3.24057746269 E-3	0.0001%
$t=60.s$	'NON_REGRESSION'	-9.73288861173 E-3	0.0001%

2.2.6 Way of loading 6 (ESSAI_CISA_C)

One carries out a test of nonregression on the constraint σ_{xy} at various moments of the loading.

σ_{xy}

Identification	Type of reference	Value of reference	Tolerance
$t=10.s$	'NON_REGRESSION'	-1.002427E+04 Pa	0.0001%
$t=30.s$	'NON_REGRESSION'	1.00516E+04 Pa	0.0001%
$t=50.s$	'NON_REGRESSION'	-1.000155E+04 Pa	0.0001%

2.2.7 Way of loading 7 (ESSAI_OEDO_C)

One carries out a test of nonregression on the voluminal deformation ϵ_{vol} and the constraint σ_{xx} at various moments of the loading.

ϵ_{vol}

Identification	Type of reference	Value of reference	Tolerance
$t=10.s$	'NON_REGRESSION'	-8.48266637218E-04	0.0001%
$t=30.s$	'NON_REGRESSION'	-1.68714233218E-03	0.0001%
$t=50.s$	'NON_REGRESSION'	-2.14894009601E-03	0.0001%

σ_{xx}

Identification	Type of reference	Value of reference	Tolerance
$t=10.s$	'NON_REGRESSION'	-49721.6863437 Pa	0.0001%
$t=30.s$	'NON_REGRESSION'	-53981.1605469 Pa	0.0001%
$t=50.s$	'NON_REGRESSION'	-56319.3772981 Pa	0.0001%

2.2.8 Way of loading 8 (ESSAI_ISOT_C)

The solutions post-are treated in the single point of the model and the values of the voluminal deformation ϵ_{vol} are compared with the results of the case test ssnv204a at various moments of the loading.

ϵ_{vol}

Identification	Type of reference	Value of reference	Tolerance
$t=10.s$	'AUTRE_ASTER'	-0.01356660	0.1%
$t=20.s$	'AUTRE_ASTER'	-0.00091215	0.1%
$t=30.s$	'AUTRE_ASTER'	-0.01591635	0.1%

2.3 Remarks

The values of reference GEFDYN are already used in three existing tests, which correspond to the first three ways of loading:

- way 1: ssnv197 [V6.04.197], modeling A
- way 2: wtnv133 [V7.31.133], modeling A
- way 3: wtnv134 [V7.31.134], modeling B

3 Problem of reference for modeling B

Identical to that described in documentation **V6.04.232**.

4 Modeling B

4.1 Characteristics of modeling

Simulation at the material point. The objective is to validate the compatibility of `CALC_ESSAI_GEOMECA` with the law of Mohr-Coulomb.

The number of temporal increments is equal to 300. The initial confining pressure is of $\sigma_0 = -50\,kPa$. The maximum axial deformation is equal to $\varepsilon_{zz}^{max} = 0{,}03\,\%$.

The convergence criteria are `RESI_GLOB_RELA` = 10^{-10}.

4.2 Sizes tested and results

The solutions are compared with the analytical solution at the final moment. They are given in terms of constraints vertical σ_{zz} and horizontal σ_{xx} , and recapitulated in the following table:

$t = 30\,sec$	Code_Aster	Analytical solution	Relative error [%]
σ_{zz}	-1,732895416041E+5	-1,732895416041E+5	0
σ_{xx}	50000.	50000.	0

Table 4.2-1 : Validation of the results for modeling B

5 Problem of reference for modeling C

5.1 Geometry

The geometry is $0D$ (modeling is of type “not material”).

5.2 Properties of material

The material is of the type of a loose sand. The elastic properties are:

- Young modulus: $E=670\,MPa$
- Poisson's ratio: $\nu=0.25$

The unelastic properties (Hujeux) are:

- power of the non-linear elastic law: $n_e=0.5$
- $\beta=29$
- $d=5.8$
- $b=0.2$
- angle of friction: $\phi=40°$
- angle of dilatancy: $\psi=40°$
- critical pressure: $P_{c0}=-150\,kPa$
- pressure of reference: $P_{ref}=-1000\,kPa$
- elastic ray of the isotropic mechanism: $r^s_{éla}=0.006$
- elastic ray of the mechanism déviatoire: $r^d_{éla}=0.06$
- $a_{mon}=0.0024$
- $a_{cyc}=0.00024$
- $c_{mon}=0.01$
- $c_{cyc}=0.005$
- $r_{hys}=0.15$
- $r_{mob}=0.9$
- $x_m=2.5$
- $\mathrm{dila}=2$

The hydraulic properties are:

- coefficient of Biot: $B=1.$
- module of compressibility of water $K_e=1.\mathrm{E}12\,Pa$ (coefficient of compressibility $1/K_e=1.\mathrm{E}-12\,Pa^{-1}$)

5.3 Boundary conditions and loadings

The way of triaxial loading cyclic not-drained is defined automatically by the macro-order **CALC_ESSAI_GEOMECA** [U4.90.21].

5.3.1 Cyclic way of loading traxial not-drained

This way is characteristic of a cyclic triaxial compression test not drained (one supposes total saturation):

- one starts from a hydrostatic state of stress: $\sigma^0_{xx}=\sigma^0_{yy}=\sigma^0_{zz}=\sigma^0=-200\,kPa$, and of a state of worthless deformations.
- one keeps then the side pressure: $\sigma_{xx}=\sigma_{yy}=-200\,kPa$, while imposing for the vertical effective constraint σ'_{zz} the cyclic loading illustrated with the Figure 5.3.1-1, of amplitude $1.1\mathrm{E}5\,Pa$ and of

median value $-200\,kPa$. This is modelled by imposing linear relations between the diagonal components of the tensor of the deformations, so that:

$$\begin{cases}\sigma_{xx}+K_e tr(\boldsymbol{\varepsilon})=\sigma^0\\ \sigma_{yy}+K_e tr(\boldsymbol{\varepsilon})=\sigma^0\\ \sigma_{zz}+K_e tr(\boldsymbol{\varepsilon})=\sigma'_{zz}\end{cases}$$

where K_e indicate the module of compressibility of water, σ^0 kept side pressure constant, and σ'_{zz} the imposed effective constraint (Figure 5.3.1-1)

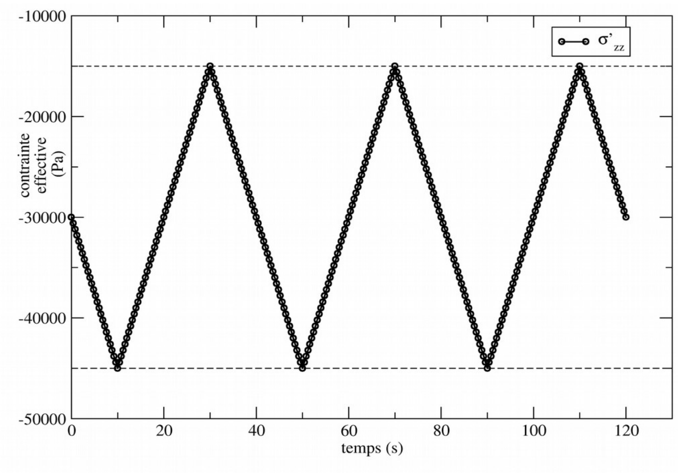

Figure 5.3.1-1: Way of loading 3

Under the keyword factor **ESSAI_TND_C** macro-order **CALC_ESSAI_GEOMECA** [U4.90.21], this way of loading corresponds to the following seizure:

- PRES_CONF$=-2.\text{E}5\,Pa$
- SIGM_IMPOSE$=1.1\text{E}5\,Pa$
- NB_CYCLE$=3$

6 Modeling C

6.1 Characteristics of modeling

Simulation at the material point.

6.2 Sizes tested and results

The solutions post-are treated in the single point of the model and are compared with values of not-regression
in terms of isotropic pressure P , with:

$$P=\frac{1}{3}tr(\boldsymbol{\sigma})$$

Identification	Type of reference	Value of reference	Tolerance
$t=70.s$	`'AUTRE_ASTER'`	-167597.Pa	1.%
$t=106.s$	`'AUTRE_ASTER'`	-65366. Pa	1.%
$t=139.8s$	`'AUTRE_ASTER'`	-3623. Pa	1.%

And of deviatoric constraint Q , with:

$$Q=\sigma_{zz}-\sigma_{xx}$$

Identification	Type of reference	Value of reference	Tolerance
$t=70.s$	`'AUTRE_ASTER'`	-110000.Pa	1.%
$t=106.s$	`'AUTRE_ASTER'`	69201. Pa	1.%
$t=139.8s$	`'AUTRE_ASTER'`	-5920. Pa	1.%

6.3 Remarks

The purpose of this modeling is to treat the passage of the line of instability in the case of a loose sand. Indeed, the diverter of the constraints Q present a maximum on this line of value lower than the instruction of imposed maximum constraint $Q_{max}=1.1\mathrm{E}+5\,Pa$. Consequently, control in constraint of the test is not possible at this place, and generally leads either to a divergence of calculation, or with a perfectly unstable false result (very important jump of constraint and deformation, to see the red curve of the Figure 6.3-1). The calculation of the exact solution passes by the swing of the test in controlled deformation when instability is detected (curved blue).

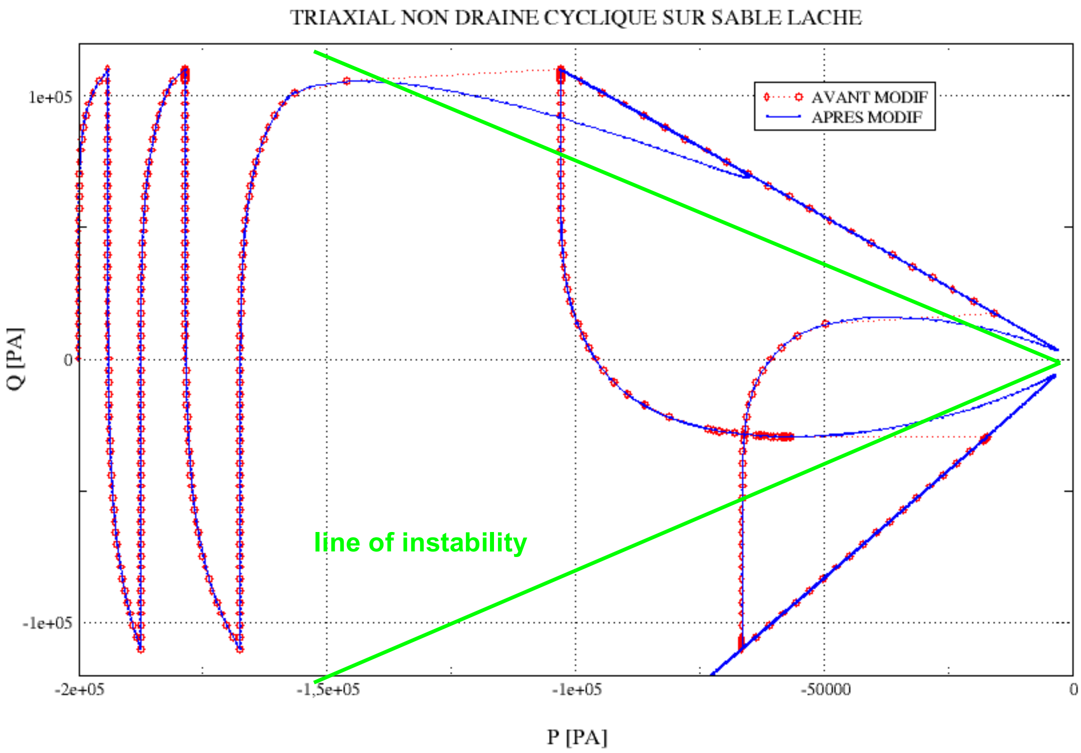

Figure 6.3-1: Comparison of the solution in controlled constraint (red) and in deformation controlled (blue) at the time of the crossing of the line of instability

7 Problem of reference for modeling D

Identical to that described in documentation **V6.04.205**.

8 Modeling D

8.1 Characteristics of modeling

The objective is to validate the compatibility of `CALC_ESSAI_GEOMECA` with the law of Iwan. The number of temporal increments is equal to 200. The initial confining pressure is of $\sigma_0 = -50\,kPa$. The convergence criteria are `RESI_GLOB_RELA` = 10^{-8}.

8.2 Sizes tested and results

The solutions are compared with the solution obtained directly by SIMU_POINT_MAT in the case test ssnv205b.

Case 1: $d\varepsilon_{xy} = 2\text{e-}5$

Identification	Type of reference	Value of reference	Tolerance
$SIXY - INST = 5$	'AUTRE_ASTER'	-1297.65875776	0.5%
$SIXY - INST = 10$	'AUTRE_ASTER'	-2343.93741663	0.5%
$SIXY - INST = 30$	'AUTRE_ASTER'	2343.86416193	0.5%
$SIXY - INST = 50$	'AUTRE_ASTER'	-2343.86423947	0.5%

Case 2: $d\varepsilon_{xy} = 2\text{e-}4$

Identification	Type of reference	Value of reference	Tolerance
$SIXY - INST = 5$	'AUTRE_ASTER'	-7532.17502946	0.5%
$SIXY - INST = 10$	'AUTRE_ASTER'	-10852.9781787	0.5%
$SIXY - INST = 20$	'AUTRE_ASTER'	4213.07055785	0.6%
$SIXY - INST = 30$	'AUTRE_ASTER'	10852.9310857	0.5%
$SIXY - INST = 40$	'AUTRE_ASTER'	-4213.07619046	0.6%
$SIXY - INST = 50$	'AUTRE_ASTER'	-10852.9310864	0.5%

Case 3: $d\varepsilon_{xy} = 2\text{e-}3$

Identification	Type of reference	Value of reference	Tolerance
$SIXY - INST = 5$	'AUTRE_ASTER'	-19270.5640459	0.5%
$SIXY - INST = 10$	'AUTRE_ASTER'	-23316.7694931	0.5%
$SIXY - INST = 20$	'AUTRE_ASTER'	15228.3800807	0.5%
$SIXY - INST = 30$	'AUTRE_ASTER'	23315.5132772	0.5%
$SIXY - INST = 40$	'AUTRE_ASTER'	-15228.1639186	0.5%
$SIXY - INST = 50$	'AUTRE_ASTER'	-23315.469541	0.5%

Table 8.2-1 : Validation of the results for modeling D

9 Summary of the results

This test validates the macro-order **CALC_ESSAI_GEOMECA** [U4.90.21] for the first three ways of loading, by taking the values of reference GEFDYN already used in existing tests (ssnv197 [V6.04.197], wtnv133 [V7.31.133], wtnv134 [V7.31.134]).