COMP012 – Test of the model of Hujeux on a Summarized

material point:

The purpose of this test is to validate the macro-command CALC_ESSAI_GEOMECA [U4.90.21] which makes it possible to simulate as in the material point four types of ways of loading characteristic of tests géomechanics:

- monotonous triaxial compression test drained
- monotonous triaxial compression test not drained
- cyclic triaxial compression test not drained
- cyclic test shear drained

These four tests are simulated with the model of Hujeux. 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 non regression for the last.

1 Problem of reference

1.1 Geometry

the geometry is $0D$ (the modelization is of standard “material point”).

1.2 Properties of the material

the elastic properties are:

- modulate isotropic compressibility: $K=516200\,kPa$
- shear modulus: $\mu=238200\,kPa$

the unelastic properties (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: $P_{c0}=-1000\,kPa$
- pressure of reference: $P_{ref}=-1000\,kPa$
- elastic radius of the isotropic mechanism: $r^s_{éla}=0.001$
- elastic radius 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: $B=1.$
- modulus of compressibility of water $K_e=1.E12\,Pa$ (coefficient of compressibility $1/K_e=1.E-12\,Pa^{-1}$)

1.3 Boundary conditions and loadings

Four ways of loading characteristic of tests géomechanics are automatically defined by macro-command `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 stress state: $\sigma^0_{xx}=\sigma^0_{yy}=\sigma^0_{zz}=\sigma^0=-5.E4\,Pa$, and of a strain state null.
- one keeps then the side pressure: $\sigma_{xx}=\sigma_{yy}=-5.E4\,Pa$, while imposing a slope of vertical strain (Figure 1.3.1-1) between $t=0$ and $t=100$, of end value $\varepsilon_{zz}=-20\%$

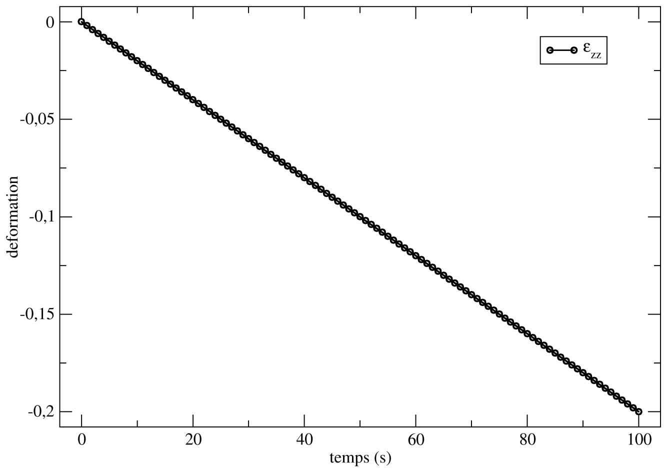

Figure 1.3.1-1: Way of loading 1

Pennies factor key word `the ESSAI_TD` of macro-command `CALC_ESSAI_GEOMECA` [U4.90.21], this way corresponds to the following seizure:

- PRES_CONF$=-5.\mathrm{E4}\,Pa$
- 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 stress state: $\sigma_{xx}^0=\sigma_{yy}^0=\sigma_{zz}^0=\sigma^0=-5.\mathrm{E4}\,Pa$, and of a strain state null.
- one keeps then the side pressure: $\sigma_{xx}=\sigma_{yy}=-5.\mathrm{E4}\,Pa$, while imposing a slope of vertical strain between $t=0$ and $t=100$, of end value $\varepsilon_{zz}=-2\%$. The squelette and the fluid are supposed to be incompressible, which one models by imposing $tr(\boldsymbol{\varepsilon})=0$. For that one imposes on the lateral distortions ε_{xx} and ε_{yy} to follow a slope such as between $t=0$ and $t=100$, these strains vary from 0 with 1% (Figure 1.3.2-1).

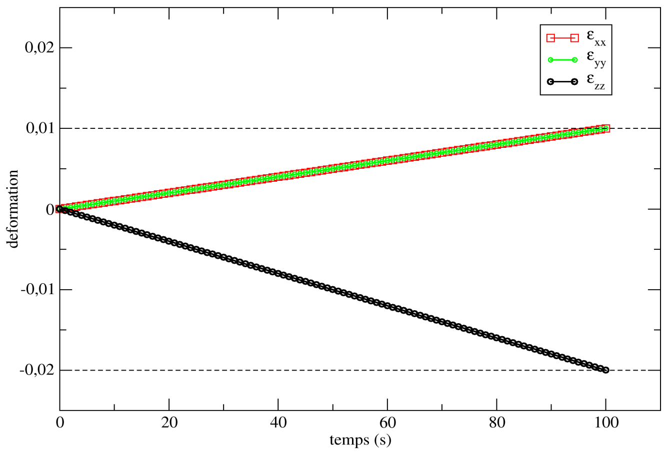

Figure 1.3.2-1: Way of loading 2

Pennies factor key word the ESSAI_TND of macro-command CALC_ESSAI_GEOMECA [U4.90.21], this way corresponds to the following seizure:

- $\text{PRES\_CONF}=-5.\text{E4}\,Pa$
- $\text{EPSI\_IMPOSE}=-0.02$

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 stress state: $\sigma_{xx}^0=\sigma_{yy}^0=\sigma_{zz}^0=\sigma^0=-3.\text{E4}\,Pa$, and of a strain state null.
- one keeps then the side pressure: $\sigma_{xx}=\sigma_{yy}=-3.\text{E4}\,Pa$, while imposing for the vertical effective stress σ'_{zz} the illustrated cyclic loading on Figure 1.3.3-1, of amplitude $1.5\text{E4}\,Pa$ and of mean value $-3.\text{E4}\,Pa$. This is modelled by imposing linear relations between the diagonal components of the tensor of the strains, 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 indicates the modulus of compressibility of water, σ^0 the side pressure kept constant, and σ'_{zz} the imposed effective stress (Figure 1.3.3-1)

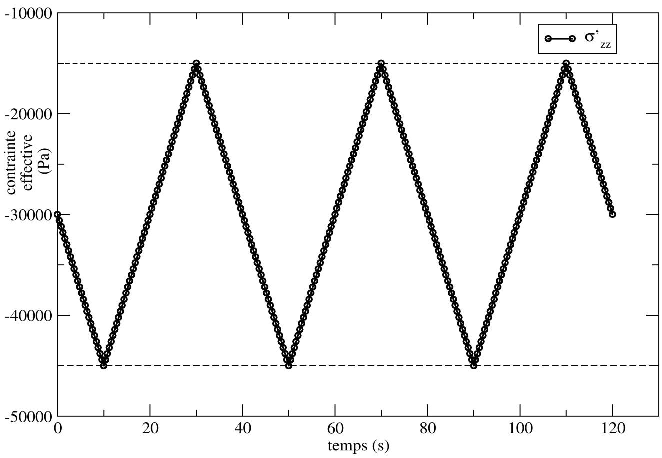

Figure 1.3.3-1: Way of loading 3

Pennies factor key word the ESSAI_TND_C of macro-command CALC_ESSAI_GEOMECA [U4.90.21], this way of loading corresponds to the following seizure:

- $\text{PRES\_CONF}=-3.\text{E4}\,Pa$
- $\text{SIGM\_IMPOSE}=1.5\text{E4}\,Pa$
- $\text{NB\_CYCLE}=3$

1.3.4 Way of loading 4

This way is characteristic of a drained cyclic shear test:

- one starts from a hydrostatic stress state: $\sigma_{xx}^0=\sigma_{yy}^0=\sigma_{zz}^0=\sigma^0=-5.\text{E4}\,Pa$, and of a strain state null.

- one keeps then the side pressure: $\sigma_{xx}=\sigma_{yy}=-5.E4\,Pa$, while imposing for ε_{xy} the cyclic loading illustrated on Figure 1.3.4-1, of amplitude 0.0195% and mean value 0.

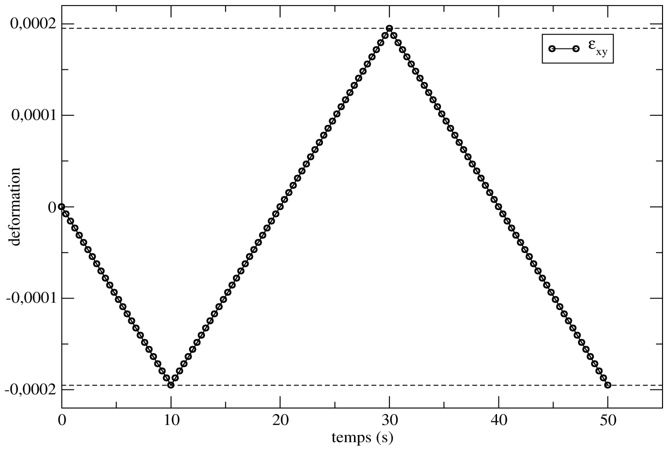

Figure 1.3.4-1: Way of loading 4

Pennies factor key word the ESSAI_CISA_C of macro-command CALC_ESSAI_GEOMECA [U4.90.21], this way corresponds to the following seizure:

- PRES_CONF $=-5.E4\,Pa$
- EPSI_IMPOSE $=1.95E-4$
- NB_CYCLE $=1$

2 Modelization A

2.1 Characteristic of the modelization

Simulation at the material point.

2.2 Quantities tested and Way

2.2.1 results of loading 1

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

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

Identification	of reference Value of reference	Tolerance	formulates
$\varepsilon_{zz}=-1\%$	SOURCE_EXTERNE" 117640	Pa 2.%	formulates
$\varepsilon_{zz}=-2\%$	"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.%

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

Standard	Identification 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 the 2

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

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

Standard	Identification 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.%

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

Standard	Identification 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 the 3

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

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

formula	Identification 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

One carries out a test of non regression on the stress σ_{xy} at various times of the loading.

σ_{xy}

Standard	Identification of reference	Value of reference	Tolerance
$t=10.s$	"NON_REGRESSION"	-9.99205E+03 Pa	0.1%
$t=30.s$	"NON_REGRESSION"	1.00784E+04 Pa	0.1%
$t=50.s$	"NON_REGRESSION"	-9.95414E+03 Pa	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], modelization A
- way 2: wtnv133 [V7.31.133], modelization A

- way 3: wtnv134 [V7.31.134], modelization B

3 Summary of the results

This test validates macro-command 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]).