WTNP116 - Problem of consolidation for permanent model HM

Summary:

One studies here a problem of consolidation in dimension 2 of a ground infinite length according to one of his dimensions. This test is used to validate several developments:

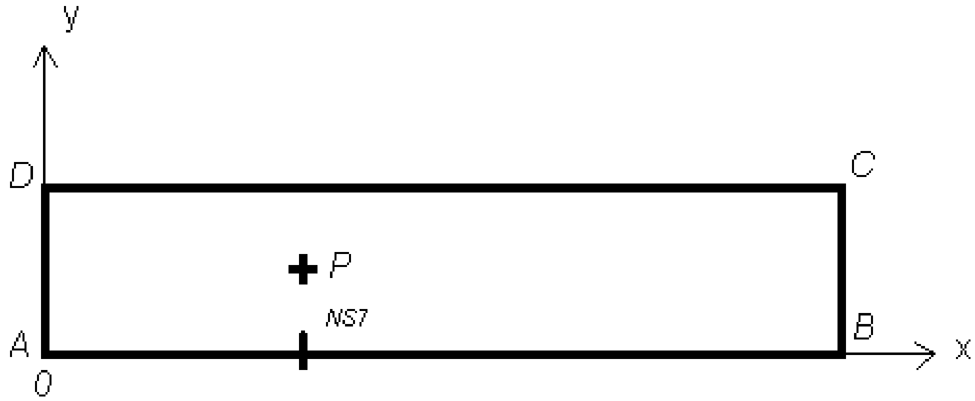
1. Hydro-mechanical modeling in saturated porous environment and permanent mode (modeling D_PLAN_HM_P). Compared to modeling D_PLAN_HM existing, this law preserves the writing of the mechanical balance of the porous environment but the temporal derivation of the mass contribution is eliminated in the writing from the conservation from the mass from water.
2. functionality of indicators of error by residue developed specifically for permanent modeling HM via the option 'ERME_ELEM' order CALC_ERREUR.
3. The resolution by chaining of the equations in HM and in particular the direction of passage of the variables of order of hydraulics towards mechanics

One thus proposes here 3 modelings, differing only by the orientation from the geometry compared to the horizontal axis. One considers a horizontal geometry (modelings A and C) and one turned geometry of an angle of $45°$ (modeling B).

1 Problème of reference

1.1 Geometry

One considers a rectangular structure of dimensions $L=5\text{m}$ according to (0x) and $l=1\text{m}$ according to (0y) .



The coordinates of the points are given in the following table:

Not	A	B	C	D	P	$NS7$
X-coordinate (m)	0	5	5	0	1.875	1.875
Ordinate (m)	0	0	1	1	0.5	0

1.2 Properties of material

One gives here only the parameters materials on which the solution depends, by knowing that the command file contains other data which do not play any part in the solution of with the dealt problem.

Liquid water	ρ : density ($kg.m^{-3}$)	1000
Coefficients material	r : homogenized density ($kg.m^{-3}$)	1600
	E : Young modulus (Pa)	225000000
	ν : Poisson's ratio (--)	0.4
	b : coefficient of Biot (–)	1
Constants	P_0 : atmospheric pressure (Pa)	100000
	g : acceleration of gravity ($m^{2.}s^{-1}$)	10

1.3 Boundary conditions and loadings

On $[AD]$, the conditions are imposed $u_x=u_y=0$ and $M.n=0$.
On $[AB]$, the conditions are imposed $u_y=0$ and $M.n=0$.
On $[DC]$, the conditions are imposed $u_y=0$ and $M.n=0$.
On $[BC]$, the conditions are imposed $\sigma\cdot n=0$ and $p=P_0=100000\,Pa$.

One supposes gravity directed according to the axis $(0\mathrm{x})$ such as $\vec{g}=-g\,\vec{x}$.

2 Reference solution

2.1 Method of calculating used for the solution of reference

Taking into account the symmetry of the boundary conditions, the solution is independent of y. For the mechanical part, the mechanical balance of the skeleton is written in projection on the axis $(0x)$:

$$(\lambda_1^M+2\lambda_2^M)\frac{\partial^2 u_x}{\partial x^2}-b\frac{\partial p}{\partial x}-rg=0$$

where λ_1^M and λ_2^M the coefficients of Lamé of material indicate. For the hydraulic part, the conservation of the water mass is written

$$\frac{\partial M_x}{\partial x}=0$$

with

$$\frac{M_x}{\rho}=\lambda^H\left(\frac{\partial p}{\partial x}-\rho g\right)$$

where λ^H indicate hydraulic conductivity. The pressure is then given by the formula

$$p=P_0+\rho g(L-x)$$

Horizontal displacements u_x are given by

$$u_x=\frac{1}{2}\frac{r-b\rho}{\lambda_1^M+2\lambda_2^M}gx(x-2L)+\frac{bP_0}{\lambda_1^M+2\lambda_2^M}x$$

2.2 Results of reference

One points out the formulas giving the coefficients of Lamé according to Young and the Poisson's ratio modulus

$$\lambda_1^M=\frac{E\nu}{(1+\nu)(1-2\nu)} \quad \text{and} \quad \lambda_2^M=\frac{E\nu}{2(1+\nu)}$$

The result of reference is the value of displacements and the pressure at the point P.

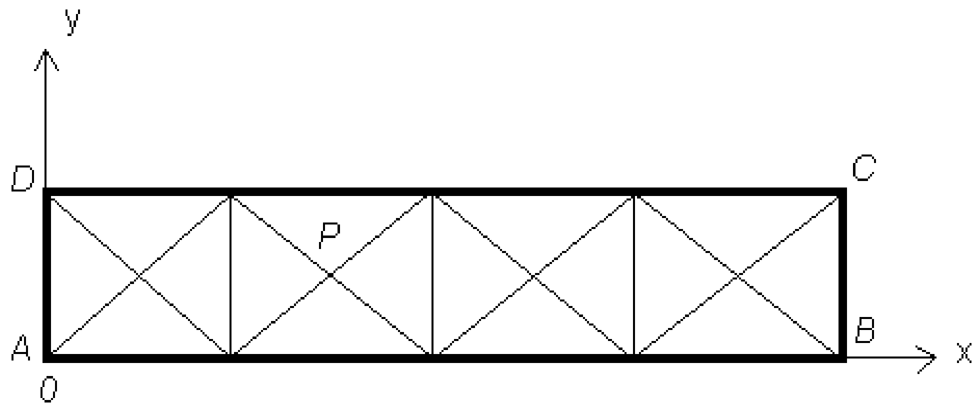
2.3 Uncertainty on the solution

Analytical solution.

3 Modeling A

3.1 Characteristics of modeling

The grid is carried out using TRIA6 modeling D_PLAN_HM_P.



It is a question of testing the solution in displacements and pressure given by *Code_Aster*. One also tests the data-processing not-regression of the calculation of the indicator of error in residue for permanent modeling HM.

3.2 Characteristics of the grid

Many nodes: 43

Many meshs and types: 16 meshs TRIA6

The grid is uniformly refined 1 time using LOBSTER.

3.3 Sizes tested and results

•Before mending of meshes

Not	Component	Reference	Code_Aster	% difference
P	DX	2,941E-04	2,941E-04	6th-03
P	DY	0.	4th-18	0.000
P	PRE1	131250.	131249	2nd-03

One also tests the data-processing not-regression of the total components ESTERG1 and ESTERG2 indicator of error. The absolute tolerance is thus severe: 10^{-13} .

Not	Component	Code_Aster	Tolerance
P	Value of ESTERG1	9.18E-31	10^{-13}
P	Value of ESTERG2	4.75E-32	10^{-13}
$NS7$	Value of ESTERG1	9.88E-31	10^{-13}

•After mending of meshes

Not	Component	Reference	Code_Aster	% difference
P	DX	2,941E-04	2,942E-04	0.006
P	DY	0.	2nd-17	0.000
P	PRE1	131250.	131249	-9.3E-04

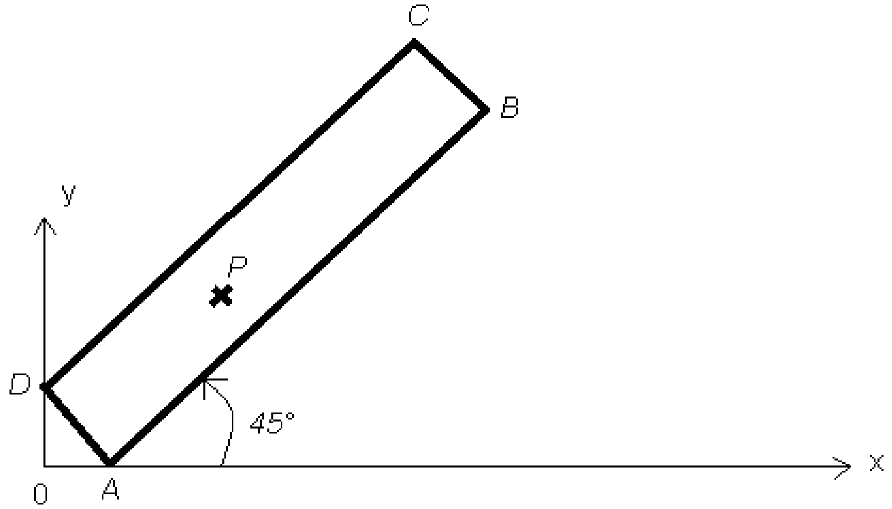
One also tests the data-processing not-regression of the total components ESTERG1 and ESTERG2 indicator of error. The absolute tolerance is thus severe: 10^{-13} .

Not	Component	Code_Aster	Tolerance
P	Value of ESTERG1	6.79E-31	10^{-13}
P	Value of ESTERG2	9.34E-33	10^{-13}

4 Modeling B

4.1 Characteristics of modeling

The grid is carried out using TRIA6 modeling D_PLAN_HM_P.



The coordinates of the points are given in the following table:

Not	A	B	C	D	P
X-coordinate ( )	0.7071	4.2426	3.5355	0	1.9743
Ordinate (m)	0	3.5355	4.2426	0.7071	1.9743

4.2 Characteristics of the grid

Many nodes: 153

Many meshs and types: 62 meshs TRIA6

4.3 Sizes tested and results

•Before mending of meshes

Not	Component	Reference	*Code_Aster*	% difference
P	DX	2,584E-04	2,5849E-04	0.035
P	DY	2,584E-04.	2,5849E-04	0.035
P	PRE1	127079.	127090.	0.008

One also tests the data-processing not-regression of the total components ESTERG1 and ESTERG2 indicator of error. The absolute tolerance is thus severe: 10^{-13} .

Not	Component	*Code_Aster*	Tolerance
P	Value of ESTERG1	4.41E-13	10^{-13}
P	Value of ESTERG2	4.89E-13	10^{-13}

•After mending of meshes

Not	Component	Reference	*Code_Aster*	% difference
P	DX	2,584E-04	2,5849E-04	0.035
P	DY	2,584E-04.	2,5849E-04	0.035
P	PRE1	127079.	127090.	0.008

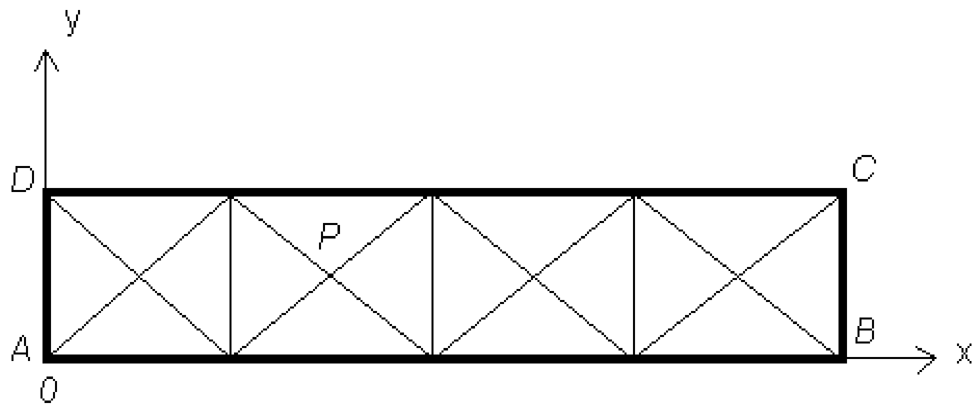
One also tests the data-processing not-regression of the total components ESTERG1 and ESTERG2 indicator of error. The absolute tolerance is thus severe: 10^{-13} .

Not	Component	*Code_Aster*	Tolerance
P	Value of ESTERG1	2,73E-14	10^{-13}
P	Value of ESTERG2	7.54E-17	10^{-13}

5 Modeling C

5.1 Characteristics of modeling

The grid is carried out using TRIA6.
For hydraulics, one uses modeling ' D_PLAN_HS'.
For mechanics, modelings are used 'D_PLAN' and 'D_PLAN_GRAD_SIGM' (only for 'ENDO_HETEROGENE'). In this modeling, the objective is primarily to validate the variable of order 'PTOT' for chaining HM (resolution of the hydraulic problem followed by the resolution of the mechanical problem) with a certain number of laws of behavior of soil mechanics: 'ELAS', 'DRUCK_PRAGER' and 'ENDO_HETEROGENE'.



One tests the solution in displacements and pressure given by *Code_Aster*.

5.2 Characteristics of the grid

Many nodes: 43

Many meshs and types: 16 meshs TRIA6

5.3 Sizes tested and results

One compares in all the nodes the digital value of the pressure with the analytical value. The maximum error on the pressure does not exceed 10^{-7} %.

For displacement, one compares the digital solution with the analytical solution at the point *P*

Not	Component	Reference	*Code_Aster*	% difference
P	DX	2,941E-04	2,941E-04	6,07E-03%

6 Summary of the results

Values provided by *Code_Code_Aster* are in perfect agreement with the values of reference.