WTNP116 - Problem of consolidation for the model permanent HM

Abstract:

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:

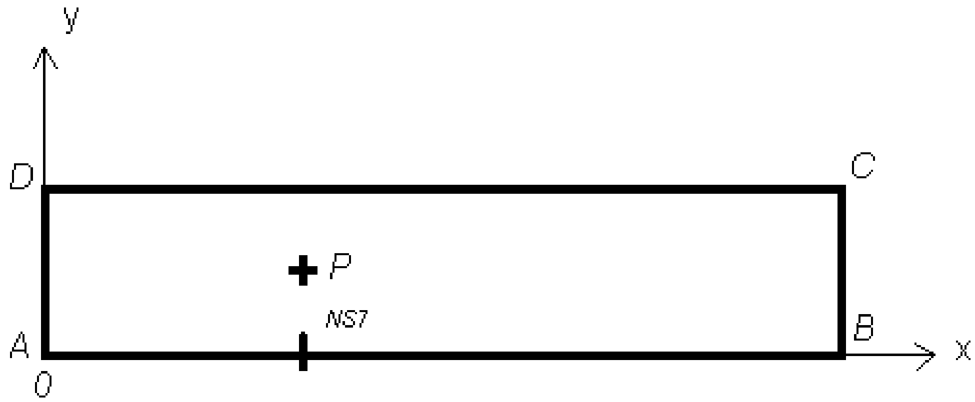
1. the Hydro-mechanical modelization in saturated porous environment and permanent mode (modelization D_PLAN_HM_P). Compared to the existing modelization D_PLAN_HM, this model preserves the writing of the mechanical equilibrium of the porous environment but the temporal derivative of the mass contribution is eliminated in the writing from the conservation from the mass from water.
2. functionality of error indicators per residue developed specifically for permanent modelization HM via option "ERME_ELEM" of the command CALC_ERREUR.
3. The resolution by sequence of the equations in HM and in particular the meaning of transition of the command variables of the hydraulics towards the mechanics

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

1 Problem of reference

1.1 Geometry

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



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
Y-coordinate (m)	0	0	1	1.0 ,5		0

1.2 Properties of the material

One gives here only materials parameters 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 ($kg.m^{-3}$) E : Young's modulus (Pa) ν : Poisson's ratio (--) b : coefficient of Biot (–)	1600 225000000 0.4 1
Constants	P_0 : atmospheric pressure (Pa) g : acceleration of gravity ($m^{2.}s^{-1}$)	100000 10

1.3 Boundary conditions and loadings

On $[AD]$, one imposes the conditions $u_x=u_y=0$ and $M.n=0$.
On $[AB]$, one imposes the conditions $u_y=0$ and $M.n=0$.
On $[DC]$, one imposes the conditions $u_y=0$ and $M.n=0$.
On $[BC]$, one imposes the conditions $\sigma\cdot n=0$ 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 reference solution

Taking into account symmetry of the boundary conditions, the solution is independent of y. For the mechanical part, the mechanical equilibrium of the squelette 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 the material indicate. For the hydraulic part, the conservation of the mass of water 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 indicates 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 the Young's modulus and of the Poisson's ratio

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

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

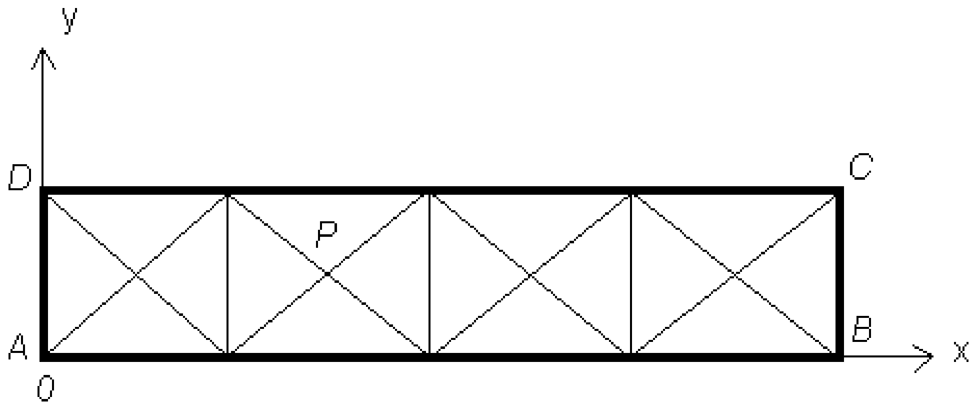
2.3 Uncertainty on the analytical

solution Solution.

3 Modelization A

3.1 Characteristic of the modelization

The mesh is carried out using TRIA6 of modelization 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 NON-regression of the computation of the error indicator in residue for permanent modelization HM.

3.2 Characteristics of the mesh

Many nodes: 43

Number of meshes and types: 16 meshes TRIA6

The mesh is uniformly refined 1 time using HOMARD.

3.3 Quantities 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 test data-processing NON-regression of the components total ESTERG1 and ESTERG2 of the error indicator. 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

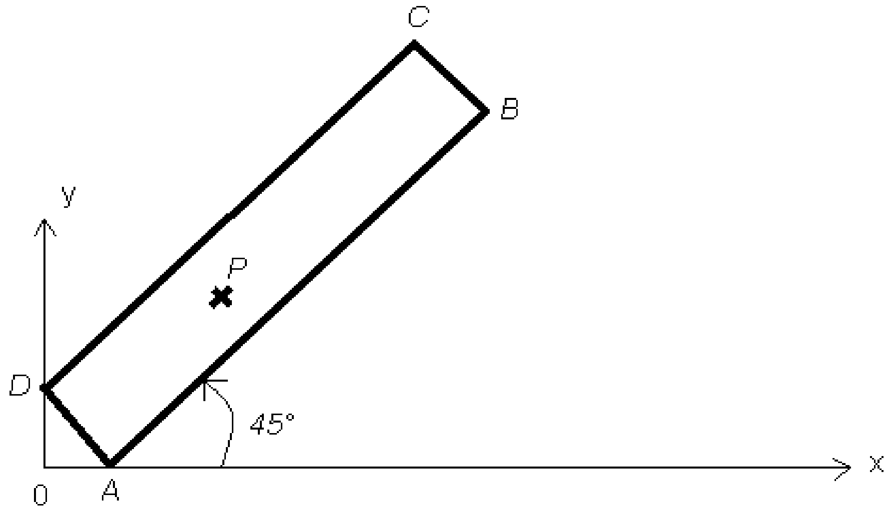
One also test data-processing NON-regression of the components total ESTERG1 and ESTERG2 of the error indicator. The absolute tolerance is thus severe: 10^{-13} .

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

4 Modelization B

4.1 Characteristic of the modelization

The mesh is carried out using `TRIA6` of modelization `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
Y-coordinate ( )	0	3,5355	4,2426	0,7071	1,9743

4.2 Characteristics of the mesh

Many nodes: 153

Number of meshes and types: 62 meshes `TRIA6`

4.3 Quantities 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 data-processing NON-regression of the components total ESTERG1 and ESTERG2 of the error indicator. 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

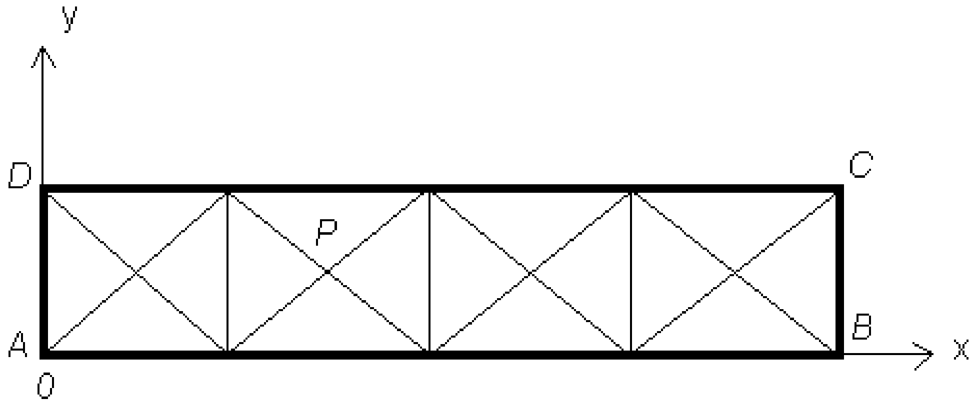
One also tests data-processing NON-regression of the components total ESTERG1 and ESTERG2 of the error indicator. The absolute tolerance is thus severe: 10^{-13} .

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

5 Modelization C

5.1 Characteristic of the modelization

The mesh is carried out using TRIA6.
For the hydraulics, one uses modelization " D_PLAN_HS".
For the mechanics, one uses modelizations "D_PLAN" and "D_PLAN_GRAD_SIGM" (only for "ENDO_HETEROGENE"). In this modelization, the purpose is primarily the command variable to validate "PTOT" for sequence HM (resolution of the hydraulic problem followed by the resolution of the mechanical problem) with a certain number of constitutive laws 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 mesh

Many nodes: 43

Number of meshes and types: 16 meshes TRIA6

5.3 Quantities tested and results

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

For displacement, one compares the numerical 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

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