WDNP102 – Reflection and absorption of one compression wave along a poroelastic column

Summary:

One tests the efficiency of the paraxial elements in hydraulic modeling. The case relates to the propagation of one compression wave in a poroelastic column. The wave is introduced and absorbed by the paraxial element located at the base of the column after being itself considered at its top. One produces two CAS-tests, one testing the 2D and the other the 3D.

1 Problem of reference

1.1 Geometry

The grid of the poroelastic column is given opposite. The axis of propagation is directed according to (OY). The total height of the column is of $25\,m$, for $0.4\,m$ of width. The first 5 meters of bottom are discretized by elements of $1\,m$ of thickness while them $20\,m$ following is discretized by elements of $0.2\,m$ of thickness. The whole of the column contains 105 elements thus.

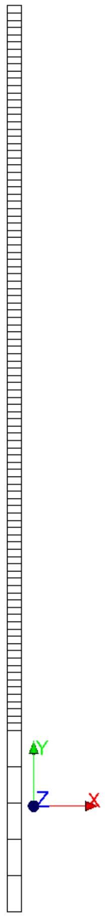


Image 1.1.1 : Grid of the column

1.2 Properties of materials

One gives in the table hereafter the properties materials of coupled hydraulic modeling. One supposes linear elastic porous material and entirely saturated with water.

From the properties materials according to, the celerity of the compression waves is given by the relation:

$$C_p=\sqrt{\frac{\lambda+2\mu}{\rho_{homo}}}=534{,}14\,m.s^{-1}$$

where λ and μ are the modules of Lamé.

Liquid water	Density ρ_l	$1000\, kg.m^{-3}$
	Compressibility K_l	$0{,}1\, MPa$
	Viscosity ν	$0{,}001$
Homogenized parameters	Intrinsic permeability K^{int}	$10^{-12}\, m^2$
	Porosity ϕ	$0{,}23$
	Homogenized density ρ_{homo}	$2105\, kg.m^{-3}$
Linear elastic solid skeleton	Module of compressibility K	$313{,}1\, MPa$
	Modulus of rigidity G	$215{,}6\, MPa$

Table 1.2-1 : Hydraulic properties of the column poro-rubber band

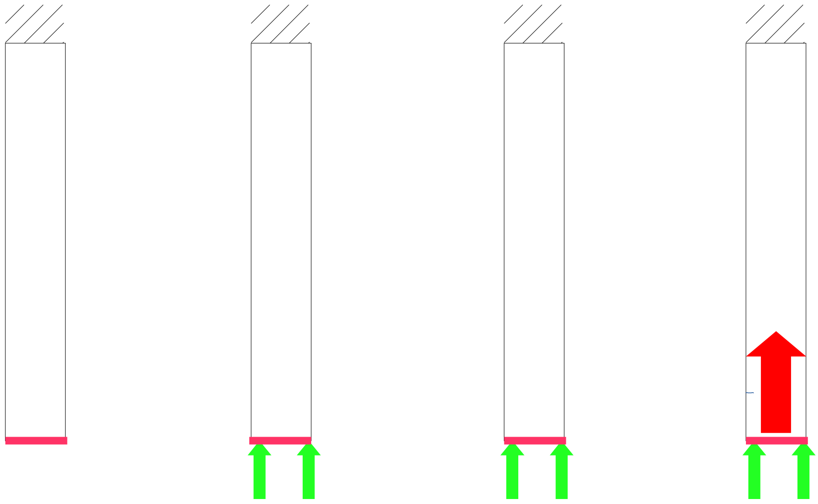
1.3 Boundary conditions and initial

One wishes to propagate upwards a wave compression in the column with a blocking of his upper part so that there is reflection of the wave at this place and propagation reverses from top to bottom. An absorbing border (paraxial element) is placed at the base of the column in order to completely deaden the considered wave.

The column being subjected to gravity, of the conditions geostatics in effective constraints and water pressure preexist initially in this one. The initial balancing of the column is not obvious and requires the following procedure:

- the base of the column, flanked paraxial element (in red), is blocked using very stiff springs. A preliminary static calculation (**figure 1**) allows to recover a loading and water pressure and stress field in balance with the boundary conditions;
- one calculates the nodal forces (resultant of the forces at the same time mechanical and hydraulic, in green) in the springs (**figure 2**);
- These nodal forces are reinjected at the base where one disables simultaneously the springs in their affecting very low stiffnesses (**figure 3**). The boundary conditions thus defined make it possible to produce an initial hydraulic state perfectly balanced;
- Dynamic calculation can take place by injecting the wave starting from the paraxial element (**figure 4**);

In order to give an account of invariance by horizontal adjustment (problem 1D), one solidarizes side displacements by a connection of the type `LIAISON_DDL`.



STAT_NON_LINE
Balance geostatics

Recovery of the nodal forces in the springs

Application of the nodal forces in the inactivated springs.
Activation of the paraxial ones

DYNA_NON_LINE
Injection of the wave by the paraxial ones

Image 1.3.1 : Procedure of initial balancing of the column

The boundary conditions, initial and of loading are summarized in the following tables:

Boundary conditions		
$HAUT$	`MECA_IMPO`	$DX=DY=DZ=0$
$COTE$	`LIAISON_DDL`	$DX_{gauche}=DX_{droit}$ $DY_{gauche}=DY_{droit}$ $DZ_{face}=DZ_{arrière}$
BAS	`FORC_NODA`	

Table 1.3-1 : boundary conditions

Initial conditions		
$COLONNE$	Geostatics	$SIXX=SIYY=SIZZ=(1-\phi)(\rho_g-\rho_l)gY$ $SIP=-PRE1=\rho_l gY$

Table 1.3-2 : initial conditions

Loadings		
$COLONNE$	`AFFE_CHAR_MECA : GRAVITY`	$g=-9{,}81\,m.s^{-2}$ according to (OY)
BAS	`AFFE_CHAR_MECA_F : ONDE_PLANE`	

Table 1.3-3 : loadings

1.4 Plane wave

The plane wave of compression is a wavelet of the Ricker type whose profile is given hereafter. It is important to note that the signal must be introduced in the form a speed according to time.

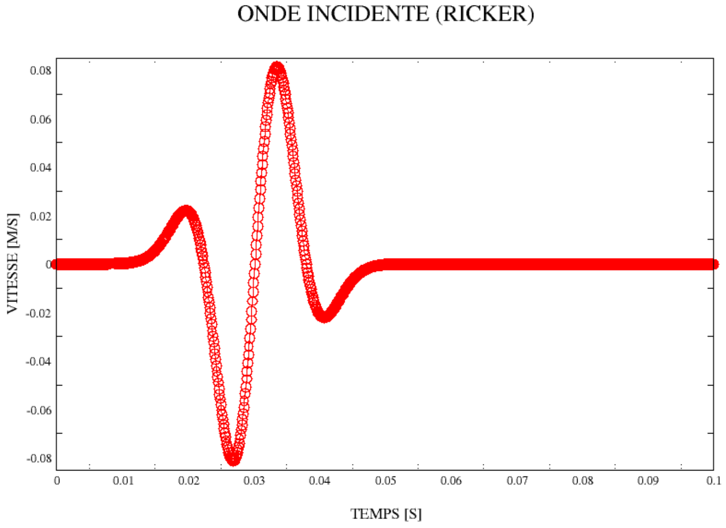


Image 1.4.1 : Incidental wavelet (Ricker)

2 Modeling A

2.1 Characteristics of modeling A

Two-dimensional case in modeling HM in plane deformations.

The discretization in time is of $10^{-3} s$ until $0{,}2\,s$.

2.2 Results

The figures below present the profiles speed and water pressure along the column according to time. One observes well a reflection of the wave at the top of the column, followed by an opposite considered wave propagation. This considered wave is then absorbed at the base by the absorbing border.

This CAS-test differs from CAS-test SDLV121 on the following points:

- it shows that the paraxial elements are also functional with modeling HM;
- it constitutes a reference closer to the encountered real problems, where it is necessary to start from a state initially balanced by taking account of a field of forces geostatics;

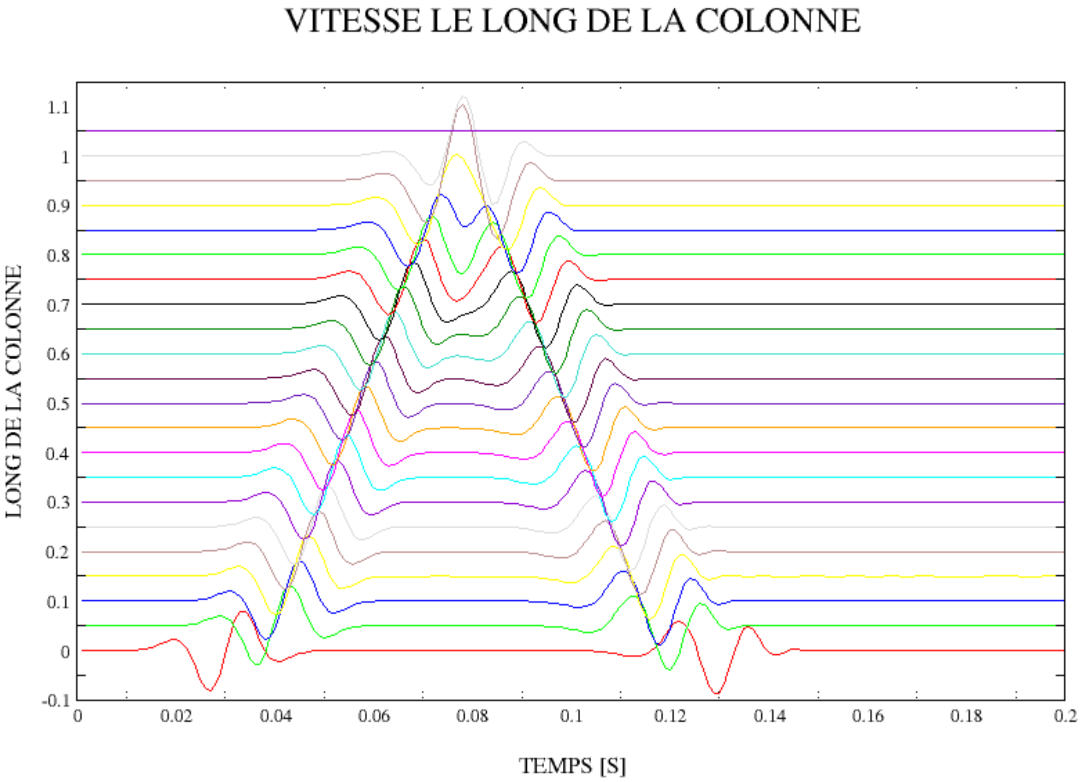


Image 2.2.1 : Propagation speed along the column

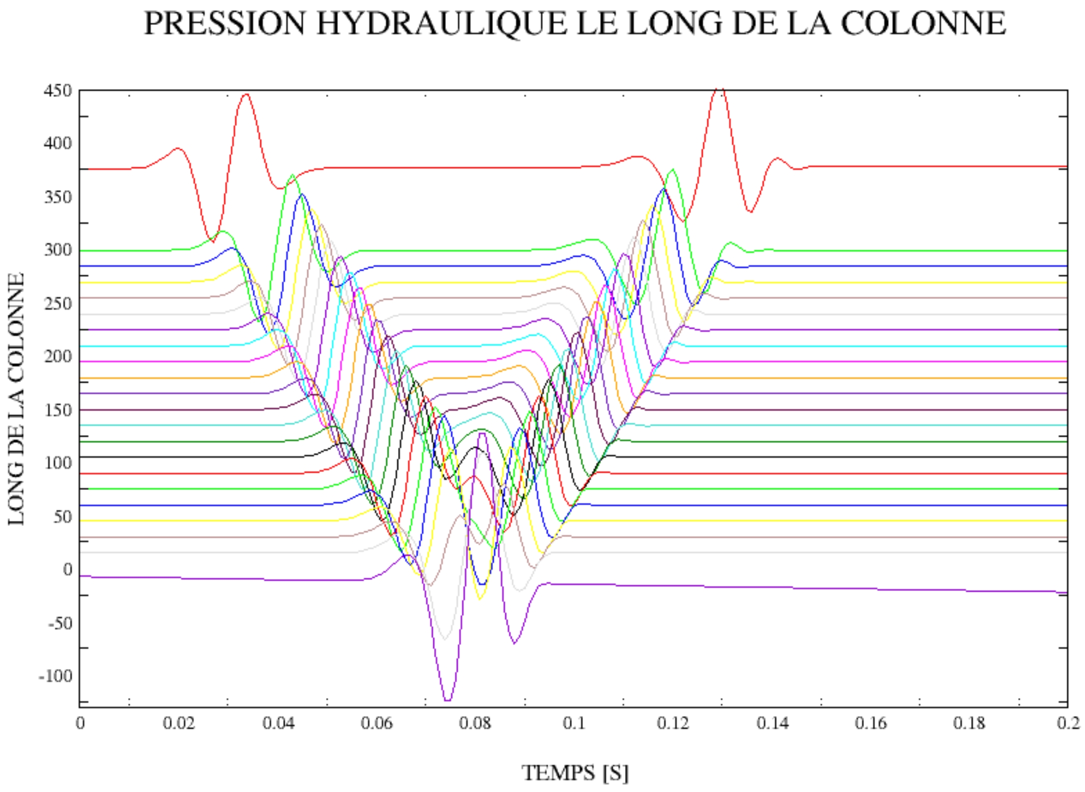


Image 2.2.2 : Propagation of the water pressure along the column

2.3 Values tested

This case test does not have a value of reference, one thus makes of them a case of nonregression. One carries out tests on three values for the speed and pressure fields hydraulic.

Y (m)	Time (s)	`VITY` *Aster*
10	0,062s	0,085759174
10	0,1s	0,085229778
10	0,18s	0

Table 2.3-1

Y (m)	Time (s)	`PRE1` *Aster*
10	0,062s	219,5247
10	0,1s	219,0596
10	0,18s	149,4430

Table 2.3-2

3 Modeling B

3.1 Characteristics of modeling B

Three-dimensional case in modeling HM in plane deformations.

The discretization in time is of $10^{-3} s$ until $0{,}2\ s$.

3.2 Results

The figures below present the profiles speed and water pressure along the column according to time. One observes well a reflection of the wave at the top of the column, followed by an opposite considered wave propagation. This considered wave is then absorbed at the base by the absorbing border.

This CAS-test differs from CAS-test SDLV121 on the following points:

- it shows that the paraxial elements are also functional with modeling HM;
- it constitutes a reference closer to the encountered real problems, where it is necessary to start from a state initially balanced by taking account of a field of forces geostatics;

3.3 Values tested

This case test does not have a value of reference, one thus makes of them a case of nonregression. One carries out tests on three values for the speed and pressure fields hydraulic.

Y (m)	**Time** (s)	`VITY` ***Aster***
10	0,062s	0,085759174
10	0,1s	0,085229778
10	0,18s	0

Table 3.3-1

Y (m)	**Time** (s)	`PRE1` ***Aster***
10	0,062s	219,5247
10	0,1s	219,0596
10	0,18s	149,4430

Table 3.3-2