Law of behavior of the porous environments: GONF_ELAS

Summary:

The model of GONF_ELAS is a model initially proposed by D. Hoxan and F. Hake [1] to describe the inflating behavior of certain types of clay. It is about a nonlinear elastic model depend on suction (this model must thus be used in an environment THHM or HHM only). This model is inspired by the model of Barcelona BBM (cf R7.01.17). It is particularly adapted under investigation behavior of the stoppers of argilE compacted (bentonite).

Contents

1 Presentation of the model and notations

This model is a Loi of behavior in rock mechanics allowing to describe the behavior of "inflating" clay materials type (bentonite). It is about a non-linear elastic model connecting the clear constraint to the pressure of swelling which it even depends on suction (or capillary pressure). It cannot be used that within the framework of the behaviors THHM and HHM.
This model rest on the following relation:

$$d\,\tilde{\sigma}=K_s(Pc)\,d\,\varepsilon_V+b\left(1+\frac{Pc}{A}\right)e^{-\beta_m\left(\frac{s}{A}\right)^2}dPc \quad (1)$$

with $\tilde{\sigma}$: clear constraint or effective constraint. Here one chooses the clear constraint (cf section 2.1).

In the version of the model available here, one does not take account of nonthe linearity of $K_s(Pc)$ nor of its dependence compared to suction. With final, one has simply $K_s(Pc)=K_0$.

With the following notations:

- K_0 is the module of incompressibility of material
- b is the coefficient of Biot
- A is a homogeneous parameter with a pressure
- β_m is a parameter without dimension
- Pc is capillary pressure

One defines also here the concept of pressure of swelling P_{gf} that one will use thereafter.

2 Mise in work of the model

2.1 Effective constraints and clear constraints

It is pointed out that formulation THM resides on the distinction between effective constraint σ' and total constraint σ, such as:

$$d\sigma = d\sigma' + d\pi \quad (2)$$

with π the hydraulic constraint such as $d\pi = -b(dPg - S\,dPc)$
where S is the saturation of liquid and Pg the gas pressure.

In the case of a formulation in clear constraint, one a:

$$d\sigma = d\tilde{\sigma} + d\pi \quad (3)$$

with π the hydraulic constraint which is then defined such as $d\pi = -b(dPg)$.

It is this formulation which is retained in the case of law GONF_ELAS what differs compared to the other laws of behavior available in THM unsaturated.

2.2 Programming of the law

In code_aster, the law is programmed in an incremental way on the average constraint (applied to the constraints clear) what gives:

$$\Delta\tilde{\sigma}_m = K_0 \Delta\varepsilon_V + b\,\Delta PG \quad (4)$$

With:

$$\tilde{\sigma}_m = \frac{1}{3} Tr(\tilde{\sigma}) \quad (5)$$

ET by introducing the function pressure of swelling with of saturated and unsaturated:

$$PG(Pc) = \begin{cases} A\left(\frac{\sqrt{\pi}}{2\sqrt{\beta_m}}\right) Erf\left(\frac{Pc}{A}\sqrt{\beta_m}\right) + \frac{1}{2\beta_m}\left(1 - e^{-\beta_m\left(\frac{Pc}{A}\right)^2}\right) & \text{si } S<1 \\ Pc \text{ si } S=1 \end{cases} \quad (6)$$

with $Erf(x) = \int_0^x e^{-\chi^2} d\chi$.

2.3 Data material and identification

Lbe parameters materials specific to the law and to inform in DEFI_MATERIAU are:

- BETAM : p arameter material without dimension corresponding to β_m law above.
- PREF : phomogeneous arameter with a pressure corresponding to A law above.

identification of β_m is done by searching the pressure of swelling. Shears $P_{gf}(Pc_0)$ pressure of swelling found by the model when one Re-saturates a sample in a test with blocked deformation and on the basis of a suction Pc_0 . One reminds that saturation, $Pc=0$, which implies that:

$$P_{gf}(Pc_0) = \int_{Pc_0}^{0} b\left(1 + \frac{Pc}{A}\right) e^{-\beta_m\left(\frac{s}{A}\right)^2} dPc \quad (7)$$

One obtains after integration:

$$\frac{P_{gf}(Pc_0)}{A}=\frac{\sqrt{\pi}}{2\sqrt{\beta_m}}Erf\left(\frac{Pc_0}{A}\sqrt{\beta_m}\right)+\frac{1}{2\beta_m}\left(1-e^{-\beta_m\left(\frac{Pc_0}{A}\right)^2}\right) \quad (8)$$

The pressure of swelling expected corresponds to the way of resaturation between the dry state ($P_c=\infty$) and the saturated state is $P_{gf}=P_{gf}(\infty)$. It is known that $Erf(\infty)=1$ and thus: $\frac{P_{gf}}{A}=\frac{\sqrt{\pi}}{2\sqrt{\beta_m}}+\frac{1}{2\beta_m}$

One from of deduced an identification from the coefficient β_m .

2.4 Internal variables at exit

There are no internal variables at exit.

3 Bibliography

1) Gerald P., Charlier R., Barnichon J.D., Known K., Shao J-F, Duveau G., Giot R., Chavant C., Hake F., Numerical Modelling of Coupled Mechanics and Gas Transfer around Radioactive Waste in length term storage. Newspaper of Theoretical and Applied Mechanics, Sofia, 2008, vol. 38, NR 1-2, pp.25-44 .

4 Checking

The law of behavior of GONF_ELAS is checked by the cases following tests:

WTNV136	Modeling 3D of the swelling of a clay	[V7.31.136]
WTNP119	Modeling planes gonflemenT of a clay	[V7.32.119]
WTNA110	Modeling axisymmetric swelling of a clay	[V7.33.110]