SSNA121 - Concrete tube subjected to an internal pressure with the model BETON_UMLV

Summary:

The objective of this test consists in validating the good taking into account of the states of traction to treat the creep of the concrete, model BETON_UMLV, under these states of tensile stresses. The test consists in applying an internal pressure to a concrete tube modelled in axisymmetric conditions.

1 Problem of reference

1.1 Geometry

One considers an infinite tube of interior ray of $20\mathrm{m}$ and of external ray $21\mathrm{m}$. The length of the tube does not intervene in the evaluation of the reference solution, but this length is fixed at $10\mathrm{m}$ for the physical modeling of the problem (illustration 1.1.1).

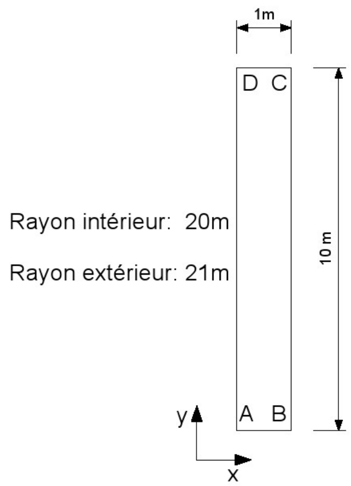

Illustration 1.1.1: Geometry of the concrete tube thickness 1m and interior ray 20m

1.2 Properties of material

The material concrete is elastic isotropic whose properties are:

- $E=31\,000\,MPa$
- $\nu=0.2$

Properties of the concrete to clean creep (model ULMV_FP) are given below:

- K_RS = $2.0\mathrm{e}11\,Pa$,
- ETA_RS = $4.0\mathrm{e}16\,Pa.s$,
- K_IS = $5.0\mathrm{e}10\,Pa$,
- ETA_IS = $1.0\mathrm{e}17\,Pa.s$,
- K_RD = $5.0\mathrm{e}11\,Pa$,
- ETA_RD = $1.0\mathrm{e}16$,
- ETA_ID = $1.0\mathrm{e}17$.

1.3 Boundary conditions and loadings

On the edge AB, one blocks vertical displacements along the axis Y.
On the edge AD, one imposes a confining pressure of $1\mathrm{MPa}$.
On the edge BC, one imposes a uniform connection for the whole of the nodes in the direction X.
On the edge CD, one imposes a uniform connection for the whole of the nodes in the direction Y.

The boundary conditions of type uniform connection ensures to model an infinite cylinder and not a cylinder with finished dimensions.

1.4 Initial conditions

nothing

2 Reference solution

2.1 Method of calculating

2.1.1 Elastic solution

The analytical solution is established on an infinite cylinder according to the direction Z, of interior ray R_{int}, of external ray R_{ext}, subjected to an interior pressure. In coordinates cylindrical and with the boundary conditions following:

$$\begin{cases} \sigma_{rr}(r=R_{\text{int}}) & = & -P \\ \sigma_{rr}(r=R_{\text{ext}}) & = & 0 \end{cases}$$

in plane constraints, the elastic solution is written:

$$\begin{cases} \sigma_{rr} = \dfrac{-R_{\text{int}}^2}{R_{\text{int}}^2-R_{\text{ext}}^2} P\left(1-\dfrac{R_{\text{ext}}}{r^2}\right) & \epsilon_{rr} = \left(\sigma_{rr}-\nu\,\sigma_{\theta\theta}\right)/E \\ \sigma_{\theta\theta} = \dfrac{-R_{\text{int}}^2}{R_{\text{int}}^2-R_{\text{ext}}^2} P\left(1+\dfrac{R_{\text{ext}}}{r^2}\right) & \epsilon_{\theta\theta} = \left(\sigma_{\theta\theta}-\nu\,\sigma_{rr}\right)/E \\ \sigma_{zz} = 0 & \epsilon_{zz} = -\nu\left(\sigma_{rr}+\sigma_{\theta\theta}\right)/E \end{cases}$$

This constitutes the reference solution of the elastic design which will be used as initial conditions with the clean calculation of creep. This solution is applied with the following physical data: $R_{\text{int}}=20\,\text{m}$ and $R_{\text{ext}}=21\,\text{m}$.

2.1.2 Solution with clean creep

The clean model of creep of the concrete, `BETON_UMLV`, is presented in details danS [R7.01.06]. One briefly points out the partly spherical and deviatoric decomposition of the deformations of clean creep. Each one of these parts is then itself separate in components in reversible or irreversible matter.
One is interested here in a particular solution of this model of the deformations differed for a constant loading and a relative humidity. The interest is especially related to the spherical part of the deformations.
The model distinguishes the loadings leading to a speed of positive deformation (state of traction) or short-term behavior and the reverse, the long-term behavior for negative speeds of deformation.

The interest of this CAS-test aims at making sure only of the good behavior of the model for the loading in traction. The following equation specifies the evolutions to be respected compared to the model:

$$\begin{cases} \epsilon_r^{sph}(t) = \dfrac{h}{k_r^{sph}}\left[1-\exp\left(\dfrac{-t\,k_r^{sph}}{\eta_r^{sph}}\right)\right]\sigma^{sph} \\ \epsilon_i^{sph}(t) = 0 \end{cases}$$

with:
ϵ_r^{sph} : spherical voluminal deformation known as in the short run
h : relative humidity of the continuous medium
t : time expressed in second
k_r^{sph} : reversible spherical apparent rigidity
η_r^{sph} : apparent viscosity

σ^{sph} : spherical part of the imposed loading

2.2 Sizes and results of reference

The only reference variable tested in this example is the irreversible voluminal deformation of creep. The value of this size remains worthless for any state of tensile stresses.

2.3 Uncertainties on the solution

Uncertainties are worthless, because it is about an analytical solution.

2.4 References

[1] BENBOUDJEMA, F.: Modeling of the deformations differed from the concrete under biaxial requests. Application to the buildings engines of nuclear power plants, Memory of D.E.A. Advanced materials – Engineering of the Structures and Envelopes, 38p. (+ additional), 1999.

[2] Reference material of Code_aster [R7.01.06]: Relation of behavior UMLV for the clean creep of the concrete.

3 Modeling A

3.1 Characteristics of modeling

A modeling is used AXIS.

3.2 Characteristics of the grid

The grid contains 50 elements of the type QUAD8 and 30 SEG3.

3.3 Sizes tested and results

One tests the irreversible voluminal deformation, value carried by the internal variable V2.

Identification	NOM_CMP	Type of reference	Value of reference	Tolerance
Mesh $M1$ - Not Gauss 1	V2	'ANALYTICAL'	0.0	10th-6

The got results are in perfect agreement with the analytical model like presents it the figure 3.3.1.

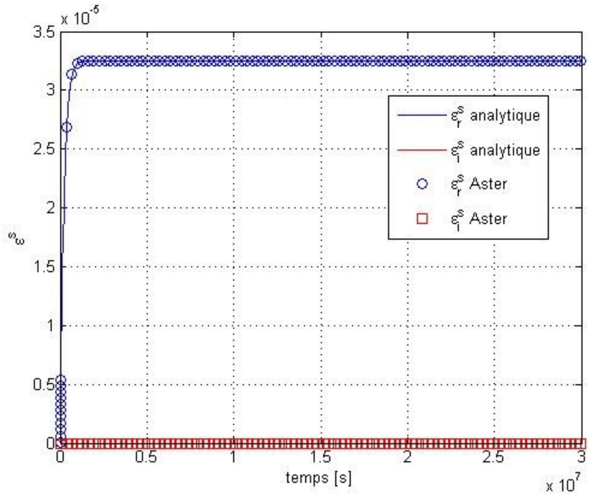

Illustration 3.3.1: Evolution of the deformations differed under interior loading from 1MPa

4 Summary of the results

The realization of this test makes it possible to make sure of the good taking into account of creep under states of traction. The results got with Code_aster are in conformity with the analytical solution.