SSNV163 - Clean computation of creep with models BETON_UMLV_FP and Summarized

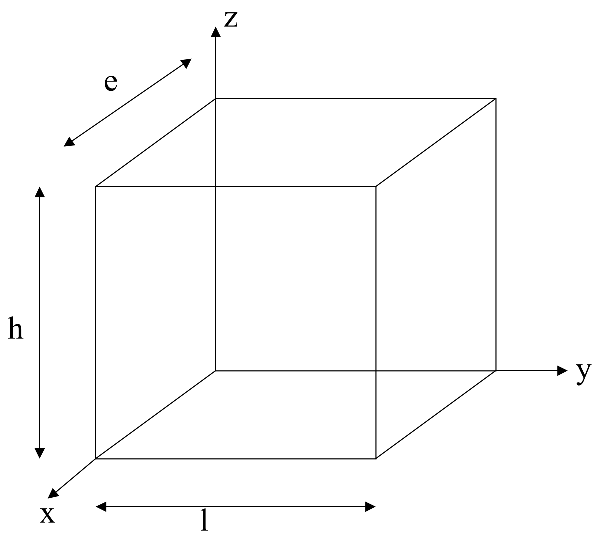
BETON_BURGER_FP:

This test makes it possible to validate the models of clean creep BETON_UMLV_FP and BETON_BURGER_FP. The results of this test are compared with the solutions analytical (BETON_UMLV_FP) or obtained according to an explicit diagram of integration (BETON_BURGER_FP) for three types of modelizations: $3D$, axisymmetric and plane stresses.

Modelization a: clean Creep test with the model BETON_UMLV_FP and a modelization 3D.
Modelization b: clean Creep test with the model BETON_UMLV_FP and a modelization AXIS.
Modelization C: Clean creep test with the model BETON_UMLV_FP and a modelization C_PLAN.
Modelization D: Clean creep test with the model BETON_BURGER_FP and a modelization 3D.
Modelization E: Clean creep test with the model BETON_BURGER_FP and a modelization AXIS.
Modelization F: Clean creep test with the model BETON_BURGER_FP and a modelization C_PLAN.

1 Problem of reference

1.1 Geometry



height:	$h=1{,}00[m]$
width:	$l=1{,}00[m]$
thickness:	$e=1{,}00[m]$

1.2 Properties of the material

$E=31\,GPa$
$\nu=0.2$

Here one informs also the curved sorption-desorption which connects the water content C to the hygroscopy h.
In this case one supposed that the numerical values of C and of h are the same ones.

Parameters specific to the clean creep of BETON_UMLV_FP :

$k_r^s=2{,}0E+5$ [MPa]	left spherical: stiffness connects associated with the squelette formed by blocks with hydrates on a mesoscopic scale
$k_i^s=5{,}0E+4$ [MPa]	spherical part: stiffness connects associated intrinsically with the hydrates on a microscopic scale
$k_r^d=5{,}0E+4$ [MPa]	deviatoric part: stiffness associated with the capacity with water adsorbed to transmit loads (*load bearing toilets*)
$\eta_r^s=4{,}0E+10$ [$MPa.s$]	left spherical: viscosity connects associated with the mechanism with diffusion within capillary porosity
$\eta_i^s=1{,}0E+11$ [$MPa.s$]	spherical part: viscosity connects associated with the mechanism with diffusion interlamellaire
$\eta_r^d=1{,}0E+10$ [$MPa.s$]	left deviatoric: viscosity associated with the water adsorbed by the averages with hydrates

$\eta_i^d = 1{,}0E+11$ [$MPa.s$] deviatoric part: viscosity of free water.

Parameters specific to the clean creep of BETON_BURGER_FP :

$k_r^s = 2{,}0E+5$ [MPa]	left spherical: stiffness connects associated with the reversible field with the differed strains
$k_r^d = 5{,}0E+4$ [MPa]	deviatoric part: stiffness associated associated with the reversible field with the differed strains
$\eta_r^s = 4{,}0E+10$ [$MPa.s$]	spherical part: viscosity connects associated with the reversible field with the differed strains
$\eta_i^s = 1{,}0E+11$ [$MPa.s$]	spherical part: viscosity connects associated with the irreversible mechanism of diffusion
$\eta_r^d = 1{,}0E+10$ [$MPa.s$]	deviatoric part: viscosity associated with the reversible field with the differed strains
$\eta_i^d = 1{,}0E+11$ [$MPa.s$]	deviatoric part: viscosity connects associated with the irreversible mechanism of diffusion
$\kappa = 3.0 \times 10^{-3}$	Normalizes unrecoverable deformations controlling to it not linearity applied to the modulus of the long-term strains

1.3 Boundary conditions and loadings

In this test, one creates a homogeneous field of drying invariant in structure, moisture is worth 100% (condition of a sealed test-tube). The mechanical loading corresponds to an one-way compression according to the vertical direction (z in $3\mathrm{D}$ or y in $2\mathrm{D}$); its intensity is of $1[MPa]$. The load is applied in $1\mathrm{s}$ and is maintained constant for 100 days.

1.4 Initial conditions

the beginning of computation is supposed time -1 . A this time there is neither field of drying, nor forced mechanical.

To time 0, one applies a field of drying corresponding to $100\ \%$ hygroscopy.

2 Reference solution

2.1 Solutions obtained for the model BETON_UMLV_FP

2.1.1 Méthode de calcul

This section presents the analytical resolution supplements problem of a body of test subjected to a stress field homogeneous and one-way applied instantaneously to initial time and maintained constant thereafter (case of a creep test in simple compression):

$$\underline{\underline{\sigma}} = \sigma_0 \underline{e}_z \otimes \underline{e}_z \qquad \text{éq 2.1-1}$$

Whose partly spherical and deviatoric decomposition is written:

$$\underline{\underline{\sigma}} = \underbrace{\frac{1}{3}\sigma_0 \underline{\underline{1}}}_{\text{partie sphérique}} + \underbrace{\frac{2}{3}\sigma_0 \underline{e}_z \otimes \underline{e}_z - \frac{1}{3}\sigma_0 \left(\underline{e}_x \otimes \underline{e}_x + \underline{e}_y \otimes \underline{e}_y\right)}_{\text{partie déviatorique}} \qquad \text{éq 2.1-2}$$

By operating a spherical/deviatoric decomposition identical to that of the stresses, the axial strain is written in the form:

$$\varepsilon_{zz} = \varepsilon^{fs}\left(\sigma_0/3\right) + \varepsilon^{fd}\left(2\sigma_0/3\right) \qquad \text{éq 2.1-3}$$

It is thus necessary successively to solve the response with a level of spherical stress and a level of deviatoric stresses.

2.1.2 Resolution of the constitutive equations of spherical creep [bib2]

the process of strain spherical of creep is controlled by the following system of equations coupled (equations [éq 2.2-1] and [éq 2.2-2], cf [R7.01.06]):

$$\dot{\varepsilon}^{fs} = \frac{1}{\eta_r^s} \cdot \left[h \cdot \sigma^s - k_r^s \cdot \varepsilon_r^{fs}\right] - \dot{\varepsilon}_i^{fs} \qquad \text{éq 2.2-1}$$

where k_r^s indicates the stiffness connects associated with the squelette formed by blocks with hydrates on a mesoscopic scale;

and η_r^s viscosity connects associated with the mechanism with diffusion within capillary porosity.

$$\dot{\varepsilon}_i^{fs} = \frac{1}{\eta_i^s} \left\langle \left[k_r^s \cdot \varepsilon^{fs} - \left(k_r^s + k_i^s\right) \cdot \varepsilon_i^{fs}\right] - \left[h\sigma^s - k_r^s \cdot \varepsilon_r^{fs}\right] \right\rangle^+ \qquad \text{éq 2.2-1}$$

where k_i^s indicates the stiffness connects intrinsically associated with the hydrates on a microscopic scale;

and η_i^s viscosity connects associated with the interfoliaceous mechanism of diffusion.

In [éq 2.2-2], the hooks $\langle \ \rangle^+$ appoint the operator of Mac Cauley: $\langle x \rangle^+ = \frac{1}{2}\left(x + |x|\right)$

The resolution of the preceding system of equations coupled requires to distinguish two cases according to the sign from the quantity ranging between the hooks from Mac Cauley. In the continuation, one presents the analytical resolution of the response to a level of stress σ^s. The relative humidity is supposed to be invariant; the medium is saturated with water.

2.1.2.1 Case of short-term creep

At initial time $t=0$, one applies a positive spherical σ^s stress. The reversible and irreversible strains of creep are equal to zero (initial conditions). The equation of the system [éq 2.2-2] is thus written:

$$\dot{\varepsilon}_i^{fs}(t=0)=\frac{1}{\eta_i^s}\left\langle\left[2\cdot k_r^s\cdot 0-k_i^s\cdot 0-\sigma^s\right]\right\rangle^+=\frac{1}{\eta_i^s}\left\langle\left[-\sigma^s\right]\right\rangle^+=0 \qquad \text{éq 2.2.1-1}$$

the irreversible strainrate of creep is thus equal to zero. One from of deduced that the irreversible strain of creep is also equal to zero. The irreversible strainrate remains equal to zero until the time $t=t_0$, defined by the relation [éq 2.2.1-2]:

$$2\cdot k_r^s\cdot\varepsilon_r^{fs}(t_0)-\sigma^s=0\Rightarrow\varepsilon_r^{fs}(t_0)=\frac{\sigma^s}{2\cdot k_r^s} \qquad \text{éq 2.2.1-2}$$

Until time $t=t_0$, the reversible strain of creep is defined by the following relation:

$$\dot{\varepsilon}_r^s=\frac{1}{\eta_r^s}\cdot\left[\sigma^s-k_r^s\cdot\varepsilon_r^s\right]\Rightarrow\varepsilon_r^s(t)=\frac{\sigma^s}{k_r^s}\cdot\left[1-\exp\left(-\frac{t}{\tau_r^s}\right)\right] \qquad \text{éq 2.2.1-3}$$

$\tau_r^s=\dfrac{\eta_r^s}{k_r^s}$ is the characteristic time associated with the reversible strain of creep. Time t_0 is thus defined by the relation [éq 2.2.1-4]:

$$\varepsilon_r^{fs}(t_0)=\frac{\sigma^s}{2\cdot k_r^s}=\frac{\sigma^s}{k_r^s}\cdot\left[1-\exp\left(-\frac{t_0}{\tau_r^s}\right)\right]\Rightarrow t_0=\ln(2)\cdot\tau_r^s\approx 0.69\cdot\tau_r^s \qquad \text{éq the 2.2.1-4}$$

reversible and irreversible strains of creep are thus determined by:

$$\begin{cases}\varepsilon_r^{fs}(t)=\dfrac{\sigma^s}{k_r^s}\cdot\left[1-\exp\left(-\dfrac{t}{\tau_r^s}\right)\right]\\ \varepsilon_i^{fs}(t)=0\end{cases} \qquad \text{éq 2.2.1-5}$$

During the computation of the strains of creep for $t>t_0$, the new initial conditions are thus:

$$\begin{cases}\varepsilon_r^{fs}(t_0)=\dfrac{\sigma^s}{2\cdot k_r^s}\\ \varepsilon_i^{fs}(t_0)=0\end{cases} \qquad \text{éq 2.2.1-6}$$

2.1.2.2 Cases of long-term creep

By expressing the reversible and irreversible strainrates of creep according to the strains of creep, one obtains the relation then:

$$\begin{cases} \dot{\varepsilon}_r^{fs} = \left(-\frac{k_r^s}{\eta_r^s} - 4\cdot\frac{k_r^s}{\eta_i^s}\right)\cdot\varepsilon_r^{fs} + \left(2\cdot\frac{k_i^s}{\eta_i^s}\right)\cdot\varepsilon_i^{fs} + \left(\frac{1}{\eta_r^s}+\frac{2}{\eta_i^s}\right)\cdot\sigma^s \\ \dot{\varepsilon}_i^{fs} = \left(2\cdot\frac{k_r^s}{\eta_i^s}\right)\cdot\varepsilon_r^{fs} + \left(-\frac{k_i}{\eta_i^s}\right)\cdot\varepsilon_i^{fs} + \left(-\frac{1}{\eta_i^s}\right)\cdot\sigma^s \end{cases} \quad \text{éq 2.2.2-1}$$

In order to simplify computations, one defines the following intermediate variables:

$$u_{rr} := \frac{k_r}{\eta_r} = \frac{1}{\tau_r},\ u_{ii} := \frac{k_i}{\eta_i} = \frac{1}{\tau_i} \text{ et } u_{ri} := \frac{k_r}{\eta_i} \quad \text{éq 2.2.2-2}$$

the system of equations [éq 2.2.2-1] can be put then in the following matric form:

$$\underline{\dot{\varepsilon}}^{fs} = \begin{bmatrix}\dot{\varepsilon}_r^{fs}\\ \dot{\varepsilon}_i^{fs}\end{bmatrix} = \underbrace{\begin{bmatrix}-u_{rr}-4\cdot u_{ri} & 2\cdot u_{ii}\\ 2\cdot u_{ri} & -u_{ii}\end{bmatrix}}_{\underline{\underline{A}}}\cdot\underbrace{\begin{bmatrix}\varepsilon_r^{fs}\\ \varepsilon_i^{fs}\end{bmatrix}}_{\underline{\varepsilon}^s} + \sigma^s\cdot\frac{1}{k_r^s}\cdot\underbrace{\begin{bmatrix}u_{rr}+2\cdot u_{ri}\\ -u_{ri}\end{bmatrix}}_{\underline{B}} \quad \text{éq 2.2.2-3}$$

I.e.:

$$\underline{\dot{\varepsilon}}^{fs} = \underline{\underline{A}}\cdot\underline{\varepsilon}^{fs} + \sigma^s\cdot\underline{B} \quad \text{éq 2.2.2-4}$$

Let us suppose that the matrix $\underline{\underline{A}}$ is *diagonalisable* (this property will be checked thereafter): $\underline{\underline{A}} = \underline{\underline{P}}\cdot\underline{\underline{D}}\cdot\underline{\underline{P}}^{-1}$ where $\underline{\underline{D}}$ indicates the diagonal matrix of the eigenvalues of the matrix $\underline{\underline{A}}$, $\underline{\underline{P}}$ the matrix of the eigenvectors of the matrix $\underline{\underline{A}}$ and $\underline{\underline{P}}^{-1}$ the opposite matrix of the matrix $\underline{\underline{P}}$. By carrying out term in the long term the product by the quantity $\underline{\underline{P}}^{-1}$, [éq 2.2.2-4] can be put in the form:

$$\underline{\dot{\varepsilon}}^{fs,*} = \underline{\underline{D}}\cdot\underline{\varepsilon}^{fs,*} + \sigma^s\cdot\underline{B}^* \text{ avec } \underline{\varepsilon}^{fs,*} = \underline{\underline{P}}^{-1}\cdot\underline{\varepsilon}^{fs} \text{ et } \underline{B}^* = \underline{\underline{P}}^{-1}\cdot\underline{B} \quad \text{éq 2.2.2-5}$$

Is λ_1 and the λ_2 eigenvalues of the matrix $\underline{\underline{A}}$. The quantities are defined:

$$\underline{\varepsilon}^{fs,*} := \begin{bmatrix}\varepsilon_1^*\\ \varepsilon_2^*\end{bmatrix} \text{ et } \underline{B}^* := \begin{bmatrix}b_1^*\\ b_2^*\end{bmatrix}$$

[éq 2.2.2-5] is written then:

$$\begin{cases}\dot{\varepsilon}_1^*(t) = \lambda_1\cdot\varepsilon_1^*(t) + \sigma^s\cdot b_1^*\\ \dot{\varepsilon}_2^*(t) = \lambda_2\cdot\varepsilon_2^*(t) + \sigma^s\cdot b_2^*\end{cases} \quad \text{éq 2.2.2-6}$$

System whose solution is written:

$$\begin{cases} \varepsilon_1^*(t) = -\dfrac{\sigma^s \cdot b_1^*}{\lambda_1} + \mu_1 \cdot \exp(\lambda_1 \cdot t) \\ \varepsilon_2^*(t) = -\dfrac{\sigma^s \cdot b_2^*}{\lambda_2} + \mu_2 \cdot \exp(\lambda_2 \cdot t) \end{cases} \begin{pmatrix} \lambda_1 \neq 0 \\ \lambda_2 \neq 0 \end{pmatrix} \quad \text{éq 2.2.2-7}$$

One can then return to initial space, by the means of the transition matrix; the reversible and irreversible strains of creep are linear combinations of ε_1^* and ε_2^*. The eigenvalues of the matrix $\underline{\underline{A}}$, λ_1 and λ_2 are obtained while solving:

$$\det(\underline{\underline{A}} - \lambda_i \cdot \underline{\underline{1}}) = 0$$
$$\Rightarrow \begin{vmatrix} -u_{rr} - 4 \cdot u_{ri} - \lambda_i & 2 \cdot u_{ii} \\ 2 \cdot u_{ri} & -u_{ii} - \lambda_i \end{vmatrix} = 0 \Rightarrow \lambda_i^2 + (u_{rr} + 4 \cdot u_{ri} + u_{ii}) \cdot \lambda_i + u_{rr} \cdot u_{ii} = 0 \quad \text{éq 2.2.2-8}$$

By noticing that u_{rr}, u_{ri} and u_{ii} are strictly positive, the discriminant is thus always strictly positive. The eigenvalues are thus real and distinct, the matrix $\underline{\underline{A}}$ is thus *diagonalisable*. In addition, none of the two eigenvalues is equal to zero $(\lambda_1 \cdot \lambda_2 = u_{rr} \cdot u_{ii} \neq 0)$. The two eigenvalues are defined by:

$$\begin{cases} \lambda_1 = \dfrac{-(u_{rr} + 4 \cdot u_{ri} + u_{ii}) - \sqrt{\Delta}}{2} \\ \lambda_2 = \dfrac{-(u_{rr} + 4 \cdot u_{ri} + u_{ii}) + \sqrt{\Delta}}{2} \end{cases} \quad \text{éq 2.2.2-9}$$

One can show that the two eigenvalues are indeed negative. Let us show that the second eigenvalue is negative. The spherical strain of creep is thus asymptotic, hypothesis put forth in the model of spherical clean creep [bib1]. Now let us determine a base of the eigenvectors $(\underline{X}_1, \underline{X}_2)$ associated with the eigenvalues λ_1 and λ_2. It is determined by solving the equation $(\underline{\underline{A}} - \lambda_i \cdot \underline{\underline{1}}) \cdot \underline{X}_i = \underline{0}$.
A particular base of eigenvectors is written:

$$\underline{X}_1 = \begin{bmatrix} x_1 \\ 1 \end{bmatrix} \text{ et } \underline{X}_2 = \begin{bmatrix} 1 \\ x_2 \end{bmatrix} \text{ avec } x_1 = \frac{\lambda_1 + u_{ii}}{2 \cdot u_{ri}} \text{ et } x_2 = \frac{2 \cdot u_{ri}}{\lambda_2 + u_{ii}} \quad \text{éq 2.2.2-10}$$

After having checked that $\underline{\underline{P}}$ can be reversed indeed, one from of deduced the solution in physical space:

$$\begin{cases} \varepsilon_r^{fs}(t) = \left[-\sigma^s \cdot \left(x_1 \cdot \frac{b_1^*}{\lambda_1} + \frac{b_2^*}{\lambda_2} \right) + x_1 \cdot \mu_1 \cdot \exp(\lambda_1 \cdot t) + \mu_2 \cdot \exp(\lambda_2 \cdot t) \right] \\ \varepsilon_i^{fs}(t) = \left[-\sigma^s \cdot \left(\frac{b_1^*}{\lambda_1} + x_2 \cdot \frac{b_2^*}{\lambda_2} \right) + \mu_1 \cdot \exp(\lambda_1 \cdot t) + x_2 \cdot \mu_2 \cdot \exp(\lambda_2 \cdot t) \right] \end{cases}$$

éq 2.2.2-11

avec

$$\begin{cases} b_1^* = \frac{1}{x_1 \cdot x_2 - 1} \cdot \left[x_2 \cdot (u_{rr} + 2 \cdot u_{ri}) + u_{ri} \right] \\ b_2^* = \frac{1}{x_1 \cdot x_2 - 1} \cdot \left[-(u_{rr} + 2 \cdot u_{ri}) - x_1 \cdot u_{ri} \right] \end{cases}$$

Lastly, μ_1 and μ_2 is defined by the relations:

$$\begin{cases} \mu_1 = -\frac{1}{(x_1 \cdot x_2 - 1) \cdot \exp[(\lambda_1 + \lambda_2) \cdot t_0]} \cdot \left[\frac{1}{2 \cdot k_r} \cdot x_2 \cdot \exp(\lambda_2 \cdot t_0) - \frac{1}{k_i} \cdot \exp(\lambda_2 \cdot t_0) \right] \\ \mu_2 = -\frac{1}{(x_1 \cdot x_2 - 1) \cdot \exp[(\lambda_1 + \lambda_2) \cdot t_0]} \cdot \left[-\frac{1}{2 \cdot k_r} \cdot \exp(\lambda_1 \cdot t_0) + \frac{1}{k_i} \cdot x_1 \cdot \exp(\lambda_1 \cdot t_0) \right] \end{cases}$$

éq 2.2.2-12

2.1.3 deviatoric Resolution of the constitutive equations of creep

the deviatoric stresses comprise a reversible part and an irreversible part (cf [R7.01.06]):

$$\underbrace{\underline{\underline{\varepsilon}}^{fd}}_{\substack{\text{déformation} \\ \text{déviatorique} \\ \text{totale}}} = \underbrace{\underline{\underline{\varepsilon}}_r^{fd}}_{\substack{\text{contribution} \\ \text{eau} \\ \text{absobée}}} + \underbrace{\underline{\underline{\varepsilon}}_i^{fd}}_{\substack{\text{contribution} \\ \text{eau} \\ \text{libre}}}$$

éq 2.3-1

the principal component jème of the total deviatoric strain is governed by the equations [éq 2.3 - 2] and [éq 2.3-3]:

$$\eta_r^d \dot{\varepsilon}_r^{d,j} + k_r^d \varepsilon_r^{d,j} = h \cdot \sigma^{d,j}$$

éq 2.3-2

where k_r^d indicates the stiffness associated with the capacity with water adsorbed to transmit loads (*load bearing toilets*);

and η_r^d viscosity associated with the water adsorbed by the averages with hydrates.

$$\eta_i^d \dot{\varepsilon}_i^{d,j} = h \cdot \sigma^{d,j}$$

éq 2.3-3

where η_i^d the viscosity of free water indicates. The system of equations [éq 2.3-2] and [éq 2.3-3] is simpler to solve than that governing the spherical behavior owing to the fact that it is decoupled. It is always supposed that moisture remains equal to 1 during all the loading. The equation [éq 2.3-2] corresponds to the viscoelastic model of Kelvin whose response with a level of stress is of exponential type. As for the equation [éq 2.3-3], the response in strain is linear with time. The total strain of creep is thus written as the sum of the contribution of a character string of Kelvin and contribution of a damper and series:

$$\varepsilon^{d,j}(t)=\left[\frac{t}{\eta_i^d}+\frac{1}{k_r^d}\left(1-e^{-\frac{k_r^d}{\eta_r^d}t}\right)\right]\cdot\sigma^{d,j}H(t) \qquad \text{éq 2.3-4}$$

2.1.4 Summary of the analytical solution

For a uniaxial loading the analytical solutions of the two components of strain are known. The contribution of the deviatoric part is written:

$$\varepsilon^{fd}(t)=\frac{2}{3}\sigma_0\cdot\left\{\frac{t}{\eta_i^d}+\frac{1}{k_r^d}\left[1-\exp\left(-\frac{k_r^d t}{\eta_r^d}\right)\right]\right\} \qquad \text{éq 2.4-1}$$

As for the contribution of the spherical part, the solution is defined on two intervals:

$$\varepsilon^{fs}(t)=\begin{cases}\dfrac{\sigma_0}{3k_r^s}\cdot\left[1-\exp\left(-\dfrac{k_r^s t}{\eta_r^s}\right)\right] & t\le\dfrac{\eta_r^s}{k_r^s}\ln 2\\ \dfrac{\sigma_0}{3}\left[\left(\dfrac{1}{k_r^s}+\dfrac{1}{k_i^s}\right)+\mu_1(1+x_1)\exp(\lambda_1 t)+\mu_2(1+x_2)\exp(\lambda_2 t)\right] & t>\dfrac{\eta_r^s}{k_r^s}\ln 2\end{cases} \qquad \text{éq 2.4-2}$$

the axial strain is a linear function of the two preceding contributions:

$$\varepsilon_{zz}=\varepsilon^{fs}(\sigma_0/3)+\varepsilon^{fd}(2\sigma_0/3) \qquad \text{éq 2.4-3}$$

2.2 Solutions obtained for the model BETON_BURGER_FP

the analytical solution was not developed for this loading of uniaxial creep. The reference solution is obtained numerically by means of a script python (accessible under the directory astest: SSNV163D.44). The diagram of integration used is explicit and sensitive to the temporal discretization employed.

2.3 Quantities and results of reference

the test is homogeneous. One tests the strain in an unspecified node.

2.4 Uncertainties on the solution

Result analytical exact for `BETON_UMLV_FP`.
Result depend on the temporal discretization employed for `BETON_BURGER_FP`.

2.5 Bibliographical references

1.BENBOUDJEMA, F.: Modelization of the strains 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 Structures and the Envelopes, 38 p. (+ additional) (1999). BENBOUDJEMA

2., F., MEFTAH, F., HEINFLING, G., LE POPE, Y.: Numerical and analytical study of the spherical part of the clean model of creep UMLV for the concrete, notes technical HT 2/25/040 /A, 56 p (2002). LE POPE

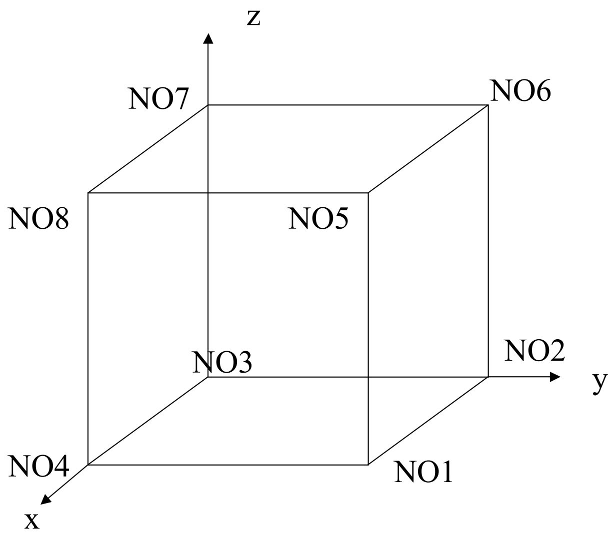
3., Y.: Behavior model UMLV for the clean creep of the concrete, Documentation of reference of Code_Aster *[R7.01* .06], 16 p (2002). FOUCAULT

4., A.: Behavior model BETON `_BURGER_FP for` the clean creep of the concrete, Documentation of reference of Code_Aster *[R7.01* .35] (2011). Modelization

3 A Characteristic

3.1 of the modelization Modelization

3D Characteristic



3.2 of the mesh Many

nodes: 8 Number of meshes
: 1 of type HEXA `8 6 of`
type QUAD4 `One defines`

the meshes following ones:

S_{ARR}	$NO3$	$NO7$	$NO8$	$NO4$
S_{AVT}	$NO1$	$NO2$	$NO6$	$NO5$
S_{DRT}	$NO1$	$NO5$	$NO8$	$NO4$
S_{GCH}	$NO3$	$NO2$	$NO6$	$NO7$
S_{INF}	$NO1$	$NO2$	$NO3$	$NO4$
S_{SUP}	$NO5$	$NO6$	$NO7$	$NO8$

The boundary conditions in displacement imposed are: On

the nodes, $NO1$ and $NO2$ $NO3$: On $NO4$ $DZ=0$
the nodes, $NO3$ and $NO7$ $NO8$: On $NO4$ $DY=0$
the nodes, $NO2$ and $NO6$ $NO7$: $NO8$ The loading $DX=0$

is consisted by the same field of drying and of the same nodal force applied $1/4$ to the four nodes of. Quantities S_{SUP}

3.3 tested and results the component

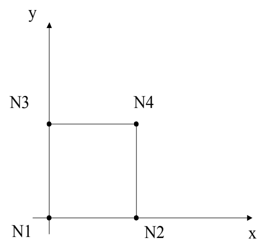
with the node ε_{zz} $NO6$ was tested. Time

Reference	Aster	% difference	0. 0
. 0	. -	1.0000	
E+00 – 3.225814	D-05 –	3.225810D-05 –	1.37E-04 9.7041
E+04 –	3.867143D-05 –	3.867140D-05 –	8.95E-05 1.8389
E+06 – 6.088552	D-05 – 6.088554	D-05 3.25	E-05 8.6400
E+06 –	1.100478D-04 – 1.100473	D-04 – 7.27	E-06 Modelization

4 B Characteristic

4.1 of the axisymmetric modelization

Modelization $2D$. Characteristics



4.2 of the mesh Many

nodes: 4 Number of meshes
: 1 of type QUAD4 4 of
type SEG2 One defines

the meshes following ones:

L_{INF} $NO1$ $NO2$
L_{DRT} $NO2$ $NO4$
L_{SUP} $NO4$ $NO3$
L_{GCH} $NO3$ $NO1$

The boundary conditions in displacement imposed are: On

: On L_{GCH} $DY=0$
: L_{INF} The loading $DX=0$

is consisted by the same field of drying and of the same nodal force applied $1/2$ to the two nodes of. Quantities L_{SUP}

4.3 tested and results the component

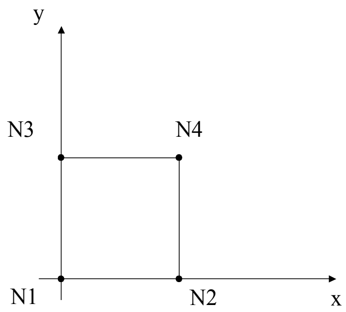
with the node ε_{yy} $NO3$ was tested Urgent

Reference	Aster	% difference	0. 0
. 0	. -	1.0000	
E+00 – 3.225814	D-05 –	3.225810D-05 –	1.37E-04 9.7041
E+04 –	3.867143D-05 –	3.867140D-05 –	8.95E-05 1.8389
E+06 – 6.088552	D-05 – 6.088554	D-05 3.25	E-05 8.6400
E+06 –	1.100478D-04 – 1.100473	D-04 – 7.27	E-06 Modelization

5 C Characteristic

5.1 of the modelization Modelization

in Plane stresses. Characteristics



5.2 of the mesh Many

nodes: 4 Number of meshes
: 1 of type QUAD4 4 of
type SEG2 One defines

the meshes following ones:

L_{INF} $NO1$ $NO2$
L_{DRT} $NO2$ $NO4$
L_{SUP} $NO4$ $NO3$
L_{GCH} $NO3$ $NO1$

The boundary conditions in displacement imposed are: On

: On L_{GCH} $DY=0$
: L_{INF} The loading $DX=0$

is consisted by the same field of drying and of the same nodal force applied $1/2$ to the two nodes of. Quantities L_{SUP}

5.3 tested and results the component

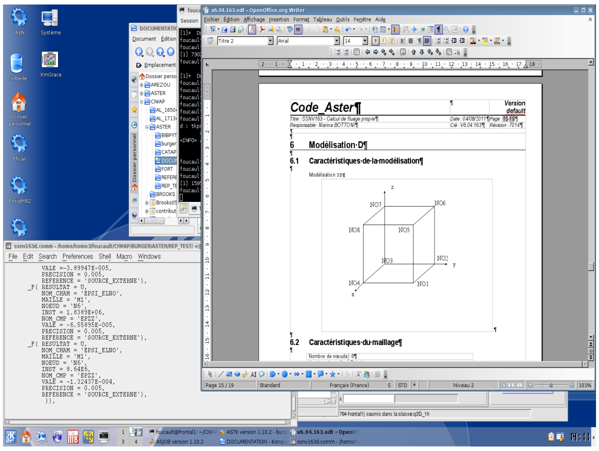
with the node ε_{yy} $NO3$ was tested Urgent

Reference	Aster	% difference	0. 0
. 0	. -	1.0000	
E+00 – 3.225814	D-05 –	3.225810D-05 –	1.40E-04 9.7041
E+04 –	3.867143D-05 –	3.867140D-05 –	9.225E-05 1.8389
E+06 – 6.088552	D-05 – 6.088554	D-05 3.08	E-05 8.6400
E+06 –	1.100478D-04 – 1.100478	D-04 – 8.22	E-06 Modelization

6 D Characteristic

6.1 of the modelization Modelization

3D Characteristic



6.2 of the mesh Many

nodes: 8 Number of meshes
: 1 of type HEXA `8 6 of`
type QUAD4 `One defines`

the meshes following ones:

S_{ARR}	$NO3$	$NO7$	$NO8$	$NO4$
S_{AVT}	$NO1$	$NO2$	$NO6$	$NO5$
S_{DRT}	$NO1$	$NO5$	$NO8$	$NO4$
S_{GCH}	$NO3$	$NO2$	$NO6$	$NO7$
S_{INF}	$NO1$	$NO2$	$NO3$	$NO4$
S_{SUP}	$NO5$	$NO6$	$NO7$	$NO8$

The boundary conditions in displacement imposed are: On

- the nodes, $NO1$ and $NO2$ $NO3$: On $NO4$ $DZ=0$
- the nodes, $NO3$ and $NO7$ $NO8$: On $NO4$ $DY=0$
- the nodes, $NO2$ and $NO6$ $NO7$: $NO8$ The loading $DX=0$

is consisted by the same field of drying and of the same nodal force applied $1/4$ to the four nodes of. Quantities S_{SUP}

6.3 tested and results the component

with the node ε_{zz} $NO6$ was tested. Standard

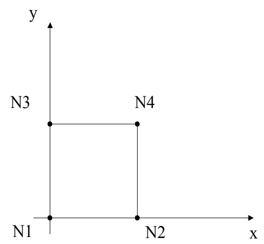
time	of Reference Reference	% Tolerance	0. SOURCE_EXTERNE
	0. –	1.0000	
E+00 SOURCE_EXTERNE	– 3.22581	D-05 0.5	9.7041
E+04 SOURCE_EXTERNE	–	3.89947D-05 0.5	1.8389

E+06 SOURCE_EXTERNE	- 6.55895	D-05 0.5	8.6400
E+06 SOURCE_EXTERNE	-	1.32437D-04 0.5	Modelization

7 B Characteristic

7.1 of the modelization Modelization

AXIS $2D$. Characteristics



7.2 of the mesh Many

nodes: 4 Number of meshes
: 1 of type QUAD4 4 of
type SEG2 One defines

the meshes following ones:

L_{INF}	$NO1$	$NO2$
L_{DRT}	$NO2$	$NO4$
L_{SUP}	$NO4$	$NO3$
L_{GCH}	$NO3$	$NO1$

The boundary conditions in displacement imposed are: On

: On L_{GCH} $DY=0$
: L_{INF} The loading $DX=0$

is consisted by the same field of drying and of the same nodal force applied $1/2$ to the two nodes of. Quantities L_{SUP}

7.3 tested and results the component

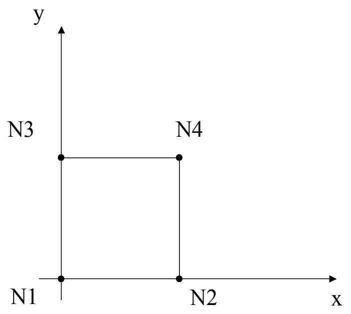
with the node ε_{yy} $NO3$ was tested Urgent

Type	of Reference Reference	% Tolerance	0. SOURCE_EXTERNE
	0. -	1.0000	
E+00 SOURCE_EXTERNE	- 3.22581	D-05 0.5	9.7041
E+04 SOURCE_EXTERNE	-	3.89947D-05 0.5	1.8389
E+06 SOURCE_EXTERNE	- 6.55895	D-05 0.5	8.6400
E+06 SOURCE_EXTERNE	-	1.32437D-04 0.5	Modelization

8 C Characteristic

8.1 of the modelization Modelization

in Plane stresses. Characteristics



8.2 of the mesh Many

nodes: 4 Number of meshes
: 1 of type QUAD4 `4 of`
type SEG2 `One defines`

the meshes following ones:

L_{INF}	*NO1*	*NO2*
L_{DRT}	*NO2*	*NO4*
L_{SUP}	*NO4*	*NO3*
L_{GCH}	*NO3*	*NO1*

The boundary conditions in displacement imposed are: On

: On L_{GCH} $DY=0$
: L_{INF} The loading $DX=0$

is consisted by the same field of drying and of the same nodal force applied $1/2$ to the two nodes of. Quantities L_{SUP}

8.3 tested and results the component

with the node ε_{yy} *NO3* was tested Urgent

Type	of Reference Reference	% Tolerance	0. SOURCE_EXTERNE
	`0. -`	1.0000	
E+00 SOURCE_EXTERNE	`- 3.22581`	D-05 0.5	9.7041
E+04 SOURCE_EXTERNE	`-`	3.89947D-05 0.5	1.8389

E+06 SOURCE_EXTERNE	- 6.55895	D-05 0.5	8.6400
E+06 SOURCE_EXTERNE	-	1.32437D-04 0.5	Summary

9 of the results

the values obtained with Code_Aster *are* in agreement with the values of reference. This same test was turned with Castem at the Laboratory of Mechanics with the University of the Marne the Valley, the same results were obtained for the model BETON_UMLV_FP .