SSLA103 - Calculation of the withdrawal of desiccation and the endogenous withdrawal on a cylinder

Summary:

The purpose of this CAS-test is to validate the calculation of the withdrawal of desiccation and the endogenous withdrawal. It also tests the possibility of making depend characteristic materials on the hydration and drying (in the case of the model of Mazars). It is about a cylinder which undergoes a drying and a uniform hydration. The temperature also varies.

The cylinder is modelled by four elements quadrangles with 8 nodes for modelings $A$, $C$, $E$ and $F$ and by an element HEXA20 for Lhas modelling $B$. For modelings $A$ and $B$, the behavior is supposed to be elastic, which makes it possible to validate the calculation of withdrawal at the same time with STAT_NON_LINE and with MECA_STATIQUE. Lhas modelling $C$ allows to validate the calculation of withdrawal with the law of MAZARS (without activation of the damage). Modeling $E$ validate the calculation of withdrawal with the law ENDO_ISO_BETON (with method of NEWTON and method IMPLEX) and modeling $F$ coupling ENDO_ISO_BETON/BETON_UMLV_FP

Results got by Code_Aster are identical to the analytical solution of reference.
1 Problem of reference

1.1 Geometry

Cylindrical test-tube.

1.2 Material properties

For modelings A and B, the material is supposed to be elastic and the characteristic materials are constant to be able to validate calculation with MECA_STATIQUE.

For Lhas modeling C, one uses the law of MAZARS and certain parameters depend on the hydration and drying.

Modeling E allows to test the law ENDO_ISOT_BETON, with method of NEWTON and IMPLEX, and modeling F coupling ENDO_ISOT_BETON / BETON_UMLV_FP, knowing that the parameters materials of the law BETON_UMLV_FP are selected so that one does not have creep and thus which one finds the behavior of the law ENDO_ISOT_BETON. In both cases, the characteristic materials are constant.

Let us announce that being given the loading (dilation, hydration and free drying), no damage develops: one thus finds in all the cases, the elastic solution.
Modeling $A$ and $B$: Isotropic elasticity

$E = 30000 \text{ MPa}$
$\nu = 0.2$
$\kappa = 1.66 \times 10^{-5} \text{ (l/m}^3\text{)}^{-1}$
$\beta_{\text{endo}} = 1.5 \times 10^{-5}$
$\alpha = 1.0 \times 10^{-5} \circ C^{-1}$

Modeling $C$: MAZARS

$E = 10000 \text{ MPa for } C = 100l/m^3$
$30000 \text{ MPa for } C = 80l/m^3$
$\nu = 0.25$ for $h = 0$
$0.15$ for $h = 1$
$\kappa = 1.66 \times 10^{-5} \text{ (l/m}^3\text{)}^{-1}$
$\beta_{\text{endo}} = 1.5 \times 10^{-5}$
$\alpha = 1.0 \times 10^{-5} \circ C^{-1}$
$A_c = 1.4$
$A_t = 1.0$ for $C = 100l/m^3$
$0.8$ for $C = 80l/m^3$
$B_c = 2000$
$B_t = 10000$ for $h = 0$
$11000$ for $h = 1$
$\varepsilon_{\text{wr}} = 10^{-4}$
$k = 0.7$

Modeling $E$: ENDO_ISOT_BETON

$E = 30000 \text{ MPa}$
$\nu = 0.2$
$\kappa = 1.66 \times 10^{-5} \text{ (l/m}^3\text{)}^{-1}$
$\beta_{\text{endo}} = 1.5 \times 10^{-5}$
$\alpha = 1.0 \times 10^{-5} \circ C^{-1}$
$\sigma_{\text{y}} = 4.0 \text{ MPa}$
$\sigma_{\text{c}} = 53.4 \text{ MPa}$
$E_{\text{t}} = -1.0 \times 10^3 \text{ MPa}$

Modeling $F$: ENDO_ISOT_BETON/BETON_UMLV_FP

See modeling $E$ +
$\sigma_{\text{y}} = 10^{19} \text{ MPa}$
$\sigma_{\text{c}} = 10^{19} \text{ MPa}$
$\eta_{\text{y}} = 10^{19} \text{ MPa.j}$
$\eta_{\text{c}} = 10^{19} \text{ MPa.j}$
$\eta_{\text{r}} = 10^{19} \text{ MPa.j}$
$\eta_{\text{d}} = 10^{19} \text{ MPa.j}$

1.3 Boundary conditions and loadings

On the side $AB$: $u_z = 0$

One varies uniformly on the structure:
1) the temperature of $T = 20^\circ C$ at initial time until $T = 120^\circ C$ at final time
2) water content of $100l/m^3$ at initial time until $80l/m^3$ at final time
3) the hydration varies from 0. at initial time with 1. at final time.
2 Reference solution

2.1 Method of calculating used for the reference solution

Being given the nature of the requests, the total deflection is only due to the withdrawal and thermal dilation. Consequently, one a:

$$\varepsilon = \varepsilon^{th} + \varepsilon^{rd} + \varepsilon^{tr} = \alpha(T - T_{ref})I_d - \kappa(C_0 - C)I_d - \beta h I_d$$

with:

- $T$, the temperature at time $t$
- $T_{ref}$, the temperature of reference
- $C_0$, water content initial (water content HR=100%)
- $C$, water content at time $t$
- $h$, the degree of hydration at time $t$
- $\alpha$, the dilation coefficient
- $\kappa$, the coefficient of withdrawal of desiccation
- $\beta$, the endogenous coefficient of withdrawal

The elastic strain being worthless in this problem, the constraints are worthless, as well as the damage in the case of modelings with the law of MAZARS and ENDO_ISOT_BETON.

2.2 Results of reference

One checks the value of the deformation after 3600 days, as well as the constraint. One also checks that the plastic deformation is worthless, as well as the damage for modelings concerned. The results are tested with STAT_NON_LINE like with MECA_STATIQUE (for modelings $A$ and $B$).
3 Modeling A

3.1 Characteristics of modeling

Modeling is of type AXIS.

The loading and the boundary conditions are modelled by:

\[
\text{FACE IMPO = _F (GROUP MA = D1, DY = 0.)}
\]

Fields of temperature TEMP1, of drying SECH1 and of hydration HYDR1 are applied to all the model.

3.2 Characteristics of the grid

Many nodes: 21
Many meshes and types: 4 QUAD8

3.3 Sizes tested and results

For calculation with STAT_NON_LINE (with BEHAVIOR), one tests the components of the tensor of the deformations EPSI_NOEU after 3600 days. It is also checked that the constraints SIEF_NOEU are worthless as well as the plastic deformation (EPSP_NOEU).

For calculation with MECA_STATIQUE, one tests the components of the tensor of the deformations EPSI_NOEU after 3600 days. It is also checked that the constraints SIGM_NOEU are worthless.

<table>
<thead>
<tr>
<th>Calculation</th>
<th>Variables</th>
<th>Moment</th>
<th>Type of Reference</th>
<th>Reference</th>
<th>tolerance</th>
</tr>
</thead>
<tbody>
<tr>
<td>STAT_NON_LINE</td>
<td>$\varepsilon_{xx}$</td>
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<td>ANALYTICAL</td>
<td>$6.53 \times 10^{-4}$</td>
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<tr>
<td></td>
<td>$\varepsilon_{yy}$</td>
<td>3600</td>
<td>ANALYTICAL</td>
<td>$6.53 \times 10^{-4}$</td>
<td>0.50%</td>
</tr>
<tr>
<td></td>
<td>$\varepsilon_{xx}^p$</td>
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<td>$\varepsilon_{yy}^p$</td>
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<td>ANALYTICAL</td>
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<tr>
<td></td>
<td>$\sigma_{xx}$</td>
<td>3600</td>
<td>ANALYTICAL</td>
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<td>1,00E-006</td>
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</table>
**Calculation MECA_STATIQUE**

<table>
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<tbody>
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<td>ANALYTICAL</td>
<td>6.53 $10^{-4}$</td>
<td>0.50%</td>
</tr>
<tr>
<td>$\varepsilon_{yy}$</td>
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</tr>
<tr>
<td>$\sigma_{xx}$</td>
<td>3600</td>
<td>ANALYTICAL</td>
<td>0.</td>
<td>1.00E-006</td>
</tr>
<tr>
<td>$\sigma_{yy}$</td>
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<td>ANALYTICAL</td>
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<td>1.00E-006</td>
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</tbody>
</table>

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4 Modeling B

4.1 Characteristics of modeling

Modeling is of type 3D.

![3D model diagram]

The loading and the boundary conditions are modelled by:

\[
\text{FACE} \_\text{IMPO} = \{ \\
\_F (\text{GROUP} \_\text{MA} = \text{FACEXY}', \text{DZ} = 0.), \\
\_F (\text{GROUP} \_\text{MA} = \text{FACEXZ}', \text{DX} = 0.), \\
\_F (\text{GROUP} \_\text{MA} = \text{FACEYZ}', \text{DY} = 0.)
\}\]

Fields of temperature \text{TEMP1}, of drying \text{SECH1} and of hydration \text{HYDR1} are applied to all the model.

4.2 Characteristics of the grid

Many nodes: 20
Many meshes and types: 1 \text{HEXA20}

4.3 Sizes tested and results

For calculation with \text{STAT\_NON\_LINE} (with \text{BEHAVIOR}), one tests the components of the tensor of the deformations \text{EPSI\_NOEU} after 3600 days. It is also checked that the constraints \text{SIEF\_NOEU} are worthless as well as the plastic deformation (\text{EPSP\_NOEU}).

For calculation with \text{MECA\_STATIQUE}, one tests the components of the tensor of the deformations \text{EPSI\_NOEU} after 3600 days. It is also checked that the constraints \text{SIGM\_NOEU} are worthless.
### Calculation STAT_NON_LINE

<table>
<thead>
<tr>
<th>Variables</th>
<th>Moment</th>
<th>Type of Reference</th>
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<th>tolerance</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\varepsilon_{xx}$</td>
<td>3600</td>
<td>ANALYTICAL</td>
<td>$6.53 \times 10^{-4}$</td>
<td>0.50%</td>
</tr>
<tr>
<td>$\varepsilon_{yy}$</td>
<td>3600</td>
<td>ANALYTICAL</td>
<td>$6.53 \times 10^{-4}$</td>
<td>0.50%</td>
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<tr>
<td>$\varepsilon_p^x$</td>
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<tr>
<td>$\varepsilon_p^y$</td>
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<td>ANALYTICAL</td>
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<td>1.00E-006</td>
</tr>
<tr>
<td>$\sigma_{xx}$</td>
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<td>ANALYTICAL</td>
<td>0.</td>
<td>1.00E-006</td>
</tr>
<tr>
<td>$\sigma_{yy}$</td>
<td>3600</td>
<td>ANALYTICAL</td>
<td>0.</td>
<td>1.00E-006</td>
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### Calculation MECA_STATIQUE

<table>
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<tr>
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<th>tolerance</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\varepsilon_{xx}$</td>
<td>3600</td>
<td>ANALYTICAL</td>
<td>$6.53 \times 10^{-4}$</td>
<td>0.50%</td>
</tr>
<tr>
<td>$\varepsilon_{yy}$</td>
<td>3600</td>
<td>ANALYTICAL</td>
<td>$6.53 \times 10^{-4}$</td>
<td>0.50%</td>
</tr>
<tr>
<td>$\sigma_{xx}$</td>
<td>3600</td>
<td>ANALYTICAL</td>
<td>0.</td>
<td>1.00E-006</td>
</tr>
<tr>
<td>$\sigma_{yy}$</td>
<td>3600</td>
<td>ANALYTICAL</td>
<td>0.</td>
<td>1.00E-006</td>
</tr>
</tbody>
</table>
5 Modeling C

5.1 Characteristics of modeling

Modeling is of type **AXIS**.

The loading and the boundary conditions are modelled by:

\[
\text{FACE_IMP} = \text{F} \quad (\text{GROUP_MA} = \text{D1}, \; \text{DY} = 0.)
\]

Fields of temperature \(\text{TEMP1}\), of drying \(\text{SECH1}\) and of hydration \(\text{HYDR1}\) are applied to all the model.

5.2 Characteristics of the grid

Many nodes: \(21\)  
Many meshes and types: \(4 \; \text{QUAD8}\)

5.3 Sizes tested and results

For calculation with **STAT_NON_LINE**, one tests the components of the tensor of the deformations \(\text{EPSI_NOEU}\) after 3600 days. It is also checked that the constraints \(\text{SIEF_NOEU}\) are worthless as well as the plastic deformation (\(\text{EPSP_NOEU}\)) and the variable of damage (\(\text{VARI_NOEU}, \; \text{V1}\)).

<table>
<thead>
<tr>
<th>Variables</th>
<th>Moment</th>
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<th>Reference</th>
<th>Tolerance</th>
</tr>
</thead>
<tbody>
<tr>
<td>(\varepsilon_{xx})</td>
<td>3600</td>
<td>ANALYTICAL</td>
<td>(6.53 \times 10^{-4})</td>
<td>0.50%</td>
</tr>
<tr>
<td>(\varepsilon_{yy})</td>
<td>3600</td>
<td>ANALYTICAL</td>
<td>(6.53 \times 10^{-4})</td>
<td>0.50%</td>
</tr>
<tr>
<td>(\varepsilon^p_{xx})</td>
<td>3600</td>
<td>ANALYTICAL</td>
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<td>1,00E-006</td>
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<tr>
<td>(\varepsilon^p_{yy})</td>
<td>3600</td>
<td>ANALYTICAL</td>
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</tr>
<tr>
<td>(\sigma_{xx})</td>
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<td>ANALYTICAL</td>
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<td>(\sigma_{yy})</td>
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<tr>
<td>(D)</td>
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<td>ANALYTICAL</td>
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<td>1,00E-006</td>
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</tbody>
</table>

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6 Modeling E

6.1 Characteristics of modeling

Modeling is of type AXIS.

```
X

\( D_1 \)
\( D_2 \)
\( D_3 \)
\( D_4 \)

N1 N2 N3 N4
N5 N6 N7 N8
N9 N10 N11 N12
N13 N14 N15 N16
N17 N18 N19 N20

Y
```

The loading and the boundary conditions are modelled by:

\[
\text{FACE\_IMPO} = \_F \ (\text{GROUP\_MA} = \ D_1, \ \text{DY} = 0.)
\]

Fields of temperature \( \text{TEMP1} \), of drying \( \text{SECH1} \) and of hydration \( \text{HYDR1} \) are applied to all the model. One uses the method of resolution of \( \text{NEWTON} \) and \( \text{IMPLEX} \) with 2 pas de charges.

6.2 Characteristics of the grid

Many nodes: 21
Many meshes and types: 4 QUAD8

6.3 Sizes tested and results

For calculation with \( \text{STAT\_NON\_LINE} \), one tests the components of the tensor of the deformations \( \text{EPSI\_NOEU} \) after 3600 days. It is also checked that the constraints \( \text{SIEF\_NOEU} \) are worthless as well as the plastic deformation \( \text{EPSP\_NOEU} \) and the variable of damage \( \text{VARI\_NOEU, V1} \).

<table>
<thead>
<tr>
<th>Variables</th>
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</thead>
<tbody>
<tr>
<td>( \varepsilon_{xx} )</td>
<td>3600</td>
<td>ANALYTICAL</td>
<td>6.53 ( 10^4 )</td>
<td>0.50%</td>
</tr>
<tr>
<td>( \varepsilon_{yy} )</td>
<td>3600</td>
<td>ANALYTICAL</td>
<td>6.53 ( 10^4 )</td>
<td>0.50%</td>
</tr>
<tr>
<td>( \varepsilon_{xx}^p )</td>
<td>3600</td>
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<td>1,00E-006</td>
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<td>( \varepsilon_{yy}^p )</td>
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<td>ANALYTICAL</td>
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<tr>
<td>( \sigma_{xx} )</td>
<td>3600</td>
<td>ANALYTICAL</td>
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<td>1,00E-006</td>
</tr>
<tr>
<td>( \sigma_{yy} )</td>
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<tr>
<td>( D )</td>
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<td>1,00E-006</td>
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7 Modeling F

7.1 Characteristics of modeling

Modeling is of type \textit{AXIS}.

The loading and the boundary conditions are modelled by:

\[ \text{FACE\_IMPO \_F (GROUP\_MA = D1, DY= 0.)} \]

Fields of temperature \textit{TEMP1}, of drying \textit{SECH1} and of hydration \textit{HYDR1} are applied to all the model.

7.2 Characteristics of the grid

Many nodes: 21
Many meshes and types: 4 \textit{QUAD8}

7.3 Sizes tested and results

For calculation with \texttt{STAT\_NON\_LINE}, one tests the components of the tensor of the deformations \texttt{EPSI\_NOEU} after 3600 days. It is also checked that the constraints \texttt{SIEF\_NOEU} are worthless as well as the plastic deformation \texttt{EPSP\_NOEU} and the variable of damage \texttt{VARI\_NOEU, V1}.

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<td>$\varepsilon_{xx}$</td>
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<td>$6.53 \times 10^{-4}$</td>
<td>0.50%</td>
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<tr>
<td>$\varepsilon_{yy}$</td>
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<tr>
<td>$\sigma_{xx}$</td>
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8 Summary of the results

Results got with Code_Aster are identical to the analytical solution. One thus validated the calculation of thermal dilation and the withdrawals endogenous and desiccation for the elastic model, that it is with STAT_NON LINE or MECA_STATIQUE, like for the law of Mazars, the law ENDO_ISOT_BETON and for the case of the coupling BETON UMLV_FP/ENDO_ISOT_BETON. Let us announce that modelings A and B also allow to validate the calculation of the withdrawals for the laws VMIS_ISOT_TRAC and VMIS_ISOT_LINE who uses the same routine as ELAS.