Long-term hydro-mechanical analysis of the GED and GCS galleries using Second Gradient model

A. Argilaga
R. Charlier
F. Collin

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Outline

1. Introduction

2. Model
   - Study of the hydraulic influence radius
   - Boundary conditions
   - Constitutive laws

3. Results
   - GED
   - GCS
   - Convergence summary

4. Conclusions
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Meuse/Haute-Marne underground research laboratory
Objectives and strategy

- Strain localization modeling

**Challenges**
- Mesh dependency

**Proposed solutions**
- Second Gradient regularization
Objectives and strategy

- Strain localization modeling

**Challenges**
- Mesh dependency

**Proposed solutions**
- Second Gradient regularization

- Long-term modelization: 100 years

**Challenges**
1. Hydraulic influence
2. Creep deformation

**Proposed solutions**
1. Study the external radius influence
2. Introduce viscosity to the model
Influence of the outer boundary

- In a 100 years period, the pore pressure will be further influenced
- 3 external radius considered in the sensitivity study
- No significative difference between 90m and 150m
- 100m is used in the following
A quarter of the gallery is used in order to decrease the numerical expenses:

- Drained boundary with constant pore water pressure ($p_{w,0}$)
- Constant total stress ($\sigma_{x,0}$, $\sigma_{y,0}$)
- Constrained displacement perpendicular to the boundary
- Constrained normal derivative of the radial displacement
- Impervious boundary

\begin{align*}
\sigma_{x,0} & \quad \sigma_{y,0} \\
\alpha = 0^\circ \\
100 \text{ [m]} & \quad 100 \text{ [m]}
\end{align*}
Excavation

Excavation deconfining
(Panet and Guenot, 1982)

<table>
<thead>
<tr>
<th>Stress (MPa)</th>
<th>Condition 1</th>
<th>Condition 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>sigma v</td>
<td>12.0</td>
<td>12.7</td>
</tr>
<tr>
<td>sigma h</td>
<td>12.0</td>
<td>12.4</td>
</tr>
<tr>
<td>sigma H</td>
<td>15.6</td>
<td>16.1</td>
</tr>
<tr>
<td>pw</td>
<td>4.7</td>
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</table>
Constitutive laws

Material laws with increasing complexity proposed:

1. Plasol: isotropic elastoplastic
2. Orthopla: anisotropic elastoplastic
3. Orthopla: anisotropic viscoplastic
4. Orthopla: +viscosity increase
5. Orthopla: +permeability evolution
Constitutive laws

Material laws with increasing complexity proposed:

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Results from laws 3 and 4 are presented in the next section.
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GED localization evolution: law 4 (+viscosity)

<table>
<thead>
<tr>
<th>Deviatoric strain increment</th>
<th>Total deviatoric strain</th>
<th>Plasticity</th>
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<tbody>
<tr>
<td>13.8 days</td>
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</tr>
<tr>
<td>19.7 days</td>
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GED localization evolution: law 4 (+viscosity)

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<td>25 days</td>
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<tr>
<td>60 days</td>
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</tbody>
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GED/GCS long-term analysis with Second Gradient
GCS localization evolution: law 4 (+viscosity)

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<td><img src="image6" alt="" /></td>
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GCS localization evolution: law 4 (+viscosity)

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GED/GCS long-term analysis with Second Gradient
Convergence summary for 100 years

**GED**

- Vertical
- Horizontal

**GCS**

- Vertical
- Horizontal

Constitutive law:
- GED: Plasol, Orthopla, Orthopla + viscosity, Orthopla + viscosity law 2, Orthopla + viscosity increment, Orthopla and K evolution
- GCS: Plasol, Orthopla, Orthopla + viscosity, Orthopla + viscosity law 2, Orthopla + viscosity increment, Orthopla and K evolution
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Conclusions

- The galleries are stable for a period of 100 years
- Convergences up to 174mm (GED) and 82mm (GCS)
- The constitutive law 4 (+ viscosity) gives the best fit
- Different localizations modes give important differences
Thanks!