Stability assessment of an abandoned underground chalk quarry

Temenuga Georgieva, Fanny Descamps, Nicolas Gonze, Jean-Pierre Tshibangu

Nancy, February 2019
Big collapse in 2015

Aerial photograph of the collapse of April 22, 2015 (CACEff, 2015).
Malogue underground quarry – impact on the surface

Total area: 67 ha
Methodology

Geometrical and geological 3D model
- Geological data
- 3D Model

Rock mass characterisation
- In situ
- Laboratory analyses

Geomechanical classification systems

Rock mass mechanical properties

Empirical approach

Numerical modeling

Behaviour of the underground openings and understanding of failure mechanisms
Data collection for Malogne quarry

**Geometry**
- Topography: 1865, 2013 (Lidarmap)
- Quarry: hangingwall, footwall, pillars geometry (2D map)

**Geology**
- Geological map
- Drillholes
- Structural analysis
- Hydrogeology (piezometric data)

**Geomechanical properties**
- Laboratory analyses
  - Property | Unit Weight | Tensile Strength | Friction Angle | Cohesion | Young's Modulus | Poisson's ratio
  - Hardground | 0.019 | 0.065 | 35.37 | 0.39 | 1 429 | 0.14
  - Phosphate Chalk | 0.017 | 0.03 | 32.5 | 0.31 | 474 | 0.34
- In situ characterization

**Land management**
- Land ownership and access permission
- Roads, railway, buildings

Total area: 67 ha
Collected data for the Malogne quarry

Geometry
- Topography: 1865, 2013 (Lidarmap)
- Quarry: hangingwall
  - footwall
  - pillars geometry (2D map)

Geology
- Geological map
- Drillholes
- Structural analysis
- Hydrogeology (piezometric data)

Geomechanical properties
- Laboratory analyses
  - Property: Unit Weight, Tensile Strength, Friction Angle, Cohesion, Young's Modulus, Poisson's ratio
  - Hardground: 0.019 MN/m³, 0.065 MPa, 35.37 deg., 0.39 MPa, 1.429 MPa, 0.14
  - Phosphate Chalk: 0.017 MN/m³, 0.03 MPa, 32.5 deg., 0.31 MPa, 474 MPa, 0.34
- In situ characterization

Land management
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- Roads, railway, buildings

Total area: 67 ha
Numerical modeling – Target area

- Rooms and Pillars geometry
- Rooms heights
- Partially Quarry floor

Highway

Railway line
Data interpretation

Footwall interpolated

- **6957** points with X, Y, Z were proceeded

<table>
<thead>
<tr>
<th>Elevation Z (m)</th>
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<tbody>
<tr>
<td>32.5</td>
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<td>40.0</td>
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<td>50.0</td>
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Hangingwall interpolated

- **3724** measurements for the rooms heights were proceeded

<table>
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<th>Heights (m)</th>
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<tr>
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Backfilled area: 
H = 0.5 m
Numerical modeling – Geometry

- Pillar width = 3.50 m
- Pillar w/h ratio = 0.78
- Room width = 4.00 m
- Room height = 4.50 m
- Dip = 3°
# Rock mass properties preliminary estimation

<table>
<thead>
<tr>
<th>Property</th>
<th>Unit Weight</th>
<th>Tensile Strength</th>
<th>Friction Angle</th>
<th>Cohesion</th>
<th>Young’s Modulus</th>
<th>Poisson’s ratio</th>
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<tr>
<td></td>
<td>MN/m³</td>
<td>MPa</td>
<td>deg.</td>
<td>MPa</td>
<td>MPa</td>
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<tr>
<td>Limon</td>
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<td>30</td>
<td>0</td>
<td>20</td>
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<tr>
<td>Tuffeau de Ciply</td>
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<td>0.01</td>
<td>31.9</td>
<td>0.16</td>
<td>243</td>
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<tr>
<td>Hardground</td>
<td>0.019</td>
<td>0.065</td>
<td>35.37</td>
<td>0.39</td>
<td>1429</td>
<td>0.14</td>
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<tr>
<td>Phosphate Chalk</td>
<td>0.017</td>
<td>0.03</td>
<td>32.5</td>
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<td>474</td>
<td>0.34</td>
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<tr>
<td>Spiennes Chalk</td>
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<td>0.32</td>
<td>58</td>
<td>0.45</td>
<td>912</td>
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Numerical modeling – preliminary results

Perfect plastic modeling of pillars (vertical section) with data about the vertical stress and yielded elements.
## Data set – parametric study

<table>
<thead>
<tr>
<th>Property</th>
<th>Unit Weight</th>
<th>Tensile Strength</th>
<th>Friction Angle</th>
<th>Cohesion</th>
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<td><strong>Set data 1</strong></td>
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<tr>
<td>(laboratory)</td>
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<td>0.065</td>
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<tr>
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<td>0.45</td>
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<td>0</td>
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<tr>
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<td>0.01</td>
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<td>0.16</td>
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<tr>
<td>Phosphate Chalk</td>
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<td>1</td>
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<td>1.9</td>
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<tr>
<td>Spiennes Chalk</td>
<td>0.017</td>
<td>0.32</td>
<td>58</td>
<td>0.45</td>
</tr>
</tbody>
</table>
Numerical modeling – parametric study

Perfect plastic modeling of pillars (vertical section) with data about the maximum principal stress

**Poor rock mass:**
- Laboratory data for the rock mass properties
- Yielded rock mass

**Fair rock mass:**
- Slightly increased rock mass properties
- Several yielded elements

**Good rock mass:**
- Increased rock mass properties
- Sporadic yielded elements
SF evaluation vs. In situ observation

Numerical modeling of pillar (vertical section) with data about the Strength Factor

Photo of slender pillar from Malogne underground quarry
Future tasks

Understanding of failure mechanisms

- Rock mass characterization: in situ and laboratory analysis
- Structural study
- Effect of water
- Rock Mass classification systems
- Numerical modeling: 3D geological and geotechnical models
- Coal mining activities influence!

Risk management solutions
THANK YOU FOR YOUR ATTENTION!

Temenuga Georgieva, Fanny Descamps, Nicolas Gonze, Jean-Pierre Tshibangu
TemenugaDimova.Georgieva@umons.ac.be