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Rock Mechanics in Civil and Environmental Engineering

IN SITU LARGE SIZE NON CONVENTIONAL SHEAR TESTS FOR THE MECHANICAL CHARACTERISATION OF A BIMROCK

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1. The site of investigation

2. Introduction to bimrocks

3. Description of in situ non conventional shear tests (BimTest)

4. Results and final remarks
1. The site of investigation

The Santa Barbara open-pit mine (Tuscany, Italy)

Six BimTests performed on the Shale-Limestone Caothic Complex bimrock (SLCC)

SLCC: dark grey clayey matrix containing heterometric calcareous rock fragments
**BIMROCK** (block-in-matrix rock): structurally complex rock mass characterised by a mixture of competent rock blocks immersed in a finer and weaker matrix.
General mechanical properties of bimrocks

“Blocks”

Rock fragments above a block/matrix size threshold defined as 5% \( L_c \)

\( L_c \): characteristic engineering dimension (Medley, 1994), which varies upon the scale of investigation

Blocks increase the tortuosity of the potential shear surface \( \rightarrow \) increase in the overall bimrock strength (increase in friction angle, decrease in cohesion)
3. BimTest

- overcome the size limitation of laboratory specimens
- investigate the mechanical behaviour of the bimrock by properly taking into account the influence of blocks
- No lateral deformation
- Constant horizontal displacement
- No vertical load
The shear surface is free to grow inside the specimen along tortuous paths: the test properly takes into account the strength increase due to the presence of blocks.
Loading apparatus

- Hydraulic cylinder, max load 170 kN
- Hydraulic pump (90 bar, 9 MPa), equipped with a 3-way compensated oil flow regulation valve (constant displacement rate)
Data acquisition system

- 50 mm LVDT displacement transducer
- 200 kN compressive force load cell
- Notebook PC with LabVIEW interface
- Power pack and electric generators
3. BimTest

Test overview

- Constant displacement 0.05 mm/s
- Specimen saturation and pore pressure is unknown: total stress analysis
3. BimTest

Beginning of failure

End of test
3. BimTest

- **P1**: Force (kN) vs. Displacement (mm)
- **P2**: Force (kN) vs. Displacement (mm)
- **P3**: Force (kN) vs. Displacement (mm) with labels: primo sframento, incrudimento, secondo sframento
- **P4**: Force (kN) vs. Displacement (mm)
- **P5**: Force (kN) vs. Displacement (mm)
- **P6**: Force (kN) vs. Displacement (mm)
3. BimTest

Force-Displacement curve

- Double-yield curve with hardening phase
- Already observed for similar in situ tests on bimrocks

![Force-Displacement Curve](image)

- **Load force**: (kN)
- **Displacement**: (mm)

- **First yield**
- **Hardening**
- **Second yield**
A pair of $c$ and $\varphi$ parameters was calculated for each specimen by means of a limit equilibrium analysis performed on cross sections of the sliding surfaces.

<table>
<thead>
<tr>
<th>Test</th>
<th>$\varphi$ (°)</th>
<th>$c$ (kPa)</th>
</tr>
</thead>
<tbody>
<tr>
<td>P1</td>
<td>43</td>
<td>6</td>
</tr>
<tr>
<td>P2</td>
<td>29</td>
<td>49</td>
</tr>
<tr>
<td>P3</td>
<td>48</td>
<td>6</td>
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</tr>
<tr>
<td>P6</td>
<td>45</td>
<td>4</td>
</tr>
</tbody>
</table>
Correlation of strength parameters with the volumetric block content (VBC) inside each specimen

- B/M threshold: 1 cm
  \((L_c: \text{max specimen linear dimension})\)

- Evaluation of VBC inside each specimen by means of in situ large-size sievings
- Very good correlation VBC – \( \varphi \) (\( R^2 = 0.85 \))
- Increase in \( \varphi \) with VBC according to the relationship \( \varphi = 0.7 \times \text{VBC} + 19.7 \)
3. BimTest

- VBC > 25% → very low $c$, slight correlation with VBC
- VBC < 25% → $c$ values close to the ones of the clayey matrix
Same trend observed in the correlation of the strength parameters with the areal block proportion above the B/M threshold

$A_b$ : areal block proportion (> 1 cm)
The BimTest resulted to be a useful test for the in situ definition of bimrock operative strength properties: it provides meaningful strength parameters which takes into account the increase in tortuosity of the shear surface due to the influence of blocks.

- Double yield force-displacement curve
- Strong dependence of the strength parameters with the VBC and $A_b$
- As expected $c_{\text{bim}} < c_{\text{matrix}}$; $\varphi_{\text{bim}} > \varphi'_{\text{matrix}}$
- Some limitations in the current configuration (total stress analysis)