Comparison of constant normal load (CNL) and constant normal stiffness (CNS) direct shear tests

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Shear Strength behavior of rock joints

Schubert (2014)
Comparison of CNL and CNS direct shear tests

Boundary conditions
Comparison of CNL and CNS direct shear tests

Test preparation

Poturovic (2014)
Performing tests

<table>
<thead>
<tr>
<th>Testing procedure</th>
<th>Test name</th>
<th>Initial stress $\sigma_0$ [Mpa]</th>
<th>Normal stiffness $K_n$ [Mpa/mm]</th>
<th>Velocity $v$ [mm/min]</th>
<th>Displacements $u$ [mm]</th>
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Material properties:
- UCS = 60 MPa
- $E = 19500$ MPa
- $\phi_B = 39^\circ$
Comparison of CNL and CNS direct shear tests

Normal and Shear strength [Mpa]

Horizontal displacements [mm]

Vertical displacements [mm]
Coefficient of friction

- Relative shearing resistance $\tau/\sigma$

\[ \arctan\left(\frac{\tau}{\sigma}\right) = \phi + i \]

- Arctan($\tau/\sigma$) = \phi + i

Graphs showing the comparison of CNL and CNS direct shear tests.
Comparison of CNL and CNS direct shear tests

Coefficient of friction

- Relative shearing resistance $\tau/\sigma$
  - $\tau/\sigma = \varphi + i$
  - Arctan($\tau/\sigma$) = $\varphi + i$

\[ \varphi + i = 45° \]
Comparison of CNL and CNS direct shear tests

Stiffness and dilation capacity

Angle of dilation $i$:

- For CNL:
  $$\tan i = \frac{dv}{du}$$

- For CNS:
  $$\tan i_f = \frac{d\sigma_n}{du} \frac{knn + K}{knn \times K}$$
  $$\tan i_f = \frac{d\sigma}{du \times k_{nn}}$$

- $K = \infty$:
Comparison of CNL and CNS direct shear tests

CNS01 $K=\infty$

CNS04 $K=5$ MPa/mm

Shear displacements [mm]

Normal displacements [mm]

-2.0  -1.5  -1.0  -0.5  0.0  0.5
0  5  10  15  20  25

-2.0  -1.5  -1.0  -0.5  0.0  0.5
0  5  10  15  20  25

Legend:
- $\varphi+i$
- $\varphi$
- Fictitious dilation if
- Measured dilation $i$
- Dilation potential
Comparison of CNL and CNS direct shear tests

CNL03 $K=0$ MPa/mm $\sigma_o=2.3$ MPa

CNL05 $K=0$ MPa/mm $\sigma_o=0.5$ MPa

Shear displacements [mm]

Normal displacements [mm]

- Graphs showing shear angle vs. shear displacement for CNL03 and CNL05 tests.

- Legend:
  - $\varphi+i$
  - $\varphi$
  - Measured dilation $i$
  - Dilation potential

- Axes:
  - X-axis: Shear displacements [mm]
  - Y-axis: Normal displacements [mm]
Dilation potential

Comparison of CNL and CNS direct shear tests

**CNL**

- $\sigma_0$ [Mpa]: 0.2, 0.5, 1.2, 2.3, 3.6, 4.9, 8, 11
- Dilation potential

**CNS**

- $K$ [Mpa/mm]: 1.25, 2.50, 5.00, 0.50, 5.00, $\infty$, $\infty$, $\infty$
- $\sigma_0$ [Mpa]: 0.65, 0.65, 0.62, 0.50, 0.50, 1.00, 2.00
- Dilation potential

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TU Graz

Institut für Feinmechanik und Materialprüfung
Subtraction of dilation

Comparison of CNL and CNS direct shear tests
Comparison of test results

### Comparison of CNL and CNS direct shear tests

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<th>$\sigma_o$</th>
<th>$K$</th>
<th>$\phi_i$</th>
<th>$\phi_{\text{eff}}$</th>
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**Mean value**

CNL

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**Mean value**

48.57 9.81 38.76
Comparison of the obtained results with the empirical methods
Conclusion

- Friction angle and dilation are key factors that determine the shear strength of rock joints.

- CNS test procedure seem more realistic and therefore more common, especially in the context of underground construction.

- Compared to CNL test procedure, the CNS requires fewer tests as the failure criterion can be determined with one test only.
Glück Auf!