Multi-Modal Loading of Rock Reinforcement under Controlled Conditions

2022/04/07
Changes in Mining Equipment & Methods

Consequences

• Autonomous / tele-remote
• In person inspection

Solutions?

• Smart Bolt / Cables
• Drones / platforms
• Photogrammetry, laser, LiDAR
Anticipated Loading

2D Concept

3D Problem

Reality

Thompson et al. (2012)

Stacey (2012)
Anticipated Loading

Resin Rebar – effect of joint location

Over coring of Installed Rockbolts

Embedment pull tests on sections

Varden & Villaescusa (2006)
Effect of Rate

Creep  Quasi-Static  “Dynamic”  Hopkinson Bar

$10^{-\infty}$  $10^{-3}$  $10^{0}$  $10^{2}$

D.I.F

$D.I.F = \left( \frac{\dot{\varepsilon}}{10^{-4}} \right)^{\alpha}$

Malvar & Crawford (1998)

Cloete & Stander (2012)
Degradation / Consumption of Capacity

Degradation of Performance

Consumption of Capacity

Hadjigeorgiou (2016)

Jones et al. (2019)
Variable Rate

Cone Bolt

![Graph showing force vs. displacement for a Variable Rate Cone Bolt. The graph includes a line representing a rapid loading of 2 m/s. The core diameter is indicated as 25 mm. The graph is based on data from Jager (1992).](image)
Sequential Loading

Quasi-static and Dynamic Loading

Knox et al. (2019)
Sequential Loading

Quasi-static and Dynamic Loading

Knox et al. (2019)
Under controlled condition

Controlled Laboratory Conditions

- Tensile
- Shear
- Impact
- Creep

Control, consequent repeatability and frequency

“Ultimately all tests are and should be considered as index tests, however, can be conducted at a reasonable cost.”

In – situ Testing

- Pull Test
- In-situ Impact
- Blast Testing
- Observations

“Better representations of conditions, however, at the mercy of production and the earths natural forces.”
Geolocation of Full Scale Apparatus

Impact Test Rig’s and Shear Test Rigs

**Impact Test Rigs**
- CanMET
- WASM
- NCM
- GiGE
- DTS, SWERIM, Sandvik Combination

**Shear Test Rigs**
- SINTEF
- NCM
- Walenstadt
Impact Test Rig Comparison

- Recent published research comparing results from four Dynamic Impact Testers
  - 6 invited, 4 participated
  - single batch of steel bars
  - same test parameters
  - results from 3 similar
Dynamic Testing
Paddled Energy Absorbing Rockbolts

After Kaiser (1996)
Dynamic Testing

Paddled Energy Absorbing Rockbolts

Li., et al., (2014)
Combination Shear and Tensile loading

Accounting for the “effect” of the rock mass

“The ultimate shear resistance of a rockbolt is between 80% - 100% of the ultimate tensile resistance” Stjern (1995)
Combination Shear and Tensile loading

Schematic of Apparatus

Load Trolley

Shear Block

Tensile Block

Hydraulic Cylinder

Load Frame

Load Cell  Internal LVDT  External LVDT

Installed Rockbolt

$F_s$, $F_r$, $\delta_s$, $\delta_r$, $\theta$, $F_t$, $\delta_t$
Combination Shear and Tensile loading

Result Overview

Yielding Rockbolt

Conventional Rockbolt
Rockbolt shear capacity

Laboratory Observations
Loading Cases

Dual Loading Case
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References