Ground Support Research at CanmetMINING

Presented by Chantale Doucet
WSN Symposium on dynamic ground support applications
Sudbury, Ontario
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What is CanmetMINING?

- CANMET Mining and Mineral Sciences Laboratories
- Part of the department of Natural Resources Canada (federal government)
- Research is funded either internally and/or externally
- Ground Control Program
- Ground Support Research – 2 researchers and 3 technicians
Program Overview

- Employees: 17
- Expertise in mining, metallurgical, civil, geological engineering and electronics

Four (4) main research areas:
- Rock mass studies
- Seismicity
- Ground Support
- Backfill

Ground Support Design under Dynamic Conditions

- Typically, for dynamic conditions, the ground support is designed for the worst-case scenario based on:
  - back-analyses of previous case histories,
  - in situ simulated dynamic events (i.e. instrumented blasts),
  - laboratory dynamic testing.
Ground Support Testing at CanmetMINING

- Laboratory and in-situ testing was chosen by CanmetMINING to fulfill their mandate on the safety of underground workers.

- Noranda’s impact testing rig transferred to CanmetMINING in 2003 to continue the research on the long term in Canada.

- While not entirely representative of *in situ* conditions, laboratory testing does allow many scenarios which affect the safety and performance of support tendons to be investigated and compared in a controlled, repeatable and cost-effective manner.

Research Mandate

1. Installation, commissioning and upgrading the NTC equipment
2. Development of testing protocols for:
   - resin/grout installation
   - Friction bolt
   - Bolt/accessories assemblies
   - Surface support
3. Upgrade the machine to test bolt/surface support assembly
4. Prepare and update technical data sheets
CanmetMINING Dynamic Testing Rig

- Original rig donated by Noranda was greatly upgraded
- Two 4.91 m high columns spaced at 1.18 m
- Load and displacements continuously measured during testing
- Loading capacity: 3 Tons
- Maximum drop height: 2 m
- Maximum impact energy: 60 kJ
- Maximum impact velocity: 6.3 m/s

Testing Configurations
Specimen Installation

- Steel tube
- Plugs over 25.4-mm holes
- Motor for powering drill and trolley drive system
- Bolt
- Drill chuck
- 10-Amp drill on trolley drive system
Static Testing of Bolts

After Stillborg 1994 & Hoek 2007
CanmetMINING static testing facility

Examples of Bolts Tested

Roofex

MCB33 FD

From Cai et al, 2010

From Wu et al, 2010

Yield-Lok

From Gradnik et al, 2010
Examples of Bolts Tested

D-Bolt

Results after one impact

From www.dynamicrocksupport.com
## Summary of Results

### «Static» Support

<table>
<thead>
<tr>
<th>Bolt Type</th>
<th>Max Impact Energy (kJ)</th>
<th>Displacement (mm)</th>
<th>Average Load (kN)</th>
<th>Test Configuration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mechanical Bolt (Ø 14.1 mm, Shell F 32 mm)</td>
<td>2.2</td>
<td>43 ± 6</td>
<td>16</td>
<td>Continuous tube</td>
</tr>
<tr>
<td>Resin Rebar (Type #6 - 20 mm)</td>
<td>5</td>
<td>5</td>
<td>160</td>
<td>Continuous tube</td>
</tr>
<tr>
<td>Resin Rebar (Type #6 - 20 mm)</td>
<td>14</td>
<td>58</td>
<td>280</td>
<td>Split-tube</td>
</tr>
</tbody>
</table>

## Summary of Results

### Yielding Support - Plowing, Sliding

<table>
<thead>
<tr>
<th>Bolt Type</th>
<th>Max Impact Energy (kJ)</th>
<th>Displacement (mm)</th>
<th>Average Load (kN)</th>
<th>Test Configuration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modified Cone Bolt MCB33 ™</td>
<td>16*</td>
<td>160 ± 72</td>
<td>134 ± 16</td>
<td>Continuous tube</td>
</tr>
<tr>
<td>Fully Debonded Cone Bolt MCB33FD ™</td>
<td>30*</td>
<td>695 ± 68</td>
<td>55 ± 11</td>
<td>Split-tube</td>
</tr>
<tr>
<td>Modified Cone Bolt MCB38 ™</td>
<td>16*</td>
<td>89 ± 25</td>
<td>155 ± 46</td>
<td>Continuous tube</td>
</tr>
<tr>
<td>Roofex Rx8 Dynamic® 800 mm sliding length</td>
<td>34*</td>
<td>914</td>
<td>58 ± 4</td>
<td>Continuous tube</td>
</tr>
<tr>
<td>Roofex Rx20 Dynamic® 800 mm sliding length</td>
<td>57*</td>
<td>840</td>
<td>99 ± 7</td>
<td>Continuous tube</td>
</tr>
<tr>
<td>Yield-Lok 750 mm of coating</td>
<td>43*</td>
<td>750</td>
<td>95 ± 7</td>
<td>Continuous tube</td>
</tr>
</tbody>
</table>

* Not maximum capacity
Summary of Results

Yielding Support - Stretching

<table>
<thead>
<tr>
<th>Bolt Type</th>
<th>Max Impact Energy (kJ)</th>
<th>Displacement (mm)</th>
<th>Average Load (kN)</th>
<th>Test Configuration</th>
</tr>
</thead>
<tbody>
<tr>
<td>D-Bolt (20 mm Ø)</td>
<td>45</td>
<td>187</td>
<td>256 ± 13</td>
<td>Split-tube</td>
</tr>
<tr>
<td>1500 mm of smooth section</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>D-Bolt (22 mm Ø)</td>
<td>56</td>
<td>225</td>
<td>279 ± 3</td>
<td>Split-tube</td>
</tr>
<tr>
<td>1500 mm of smooth section</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Results at 30 kJ

![Graph showing load vs. displacement for different bolt types at 30 kJ]
Examples of Energy Capacity

Impact energy, IE (kJ)

Displacement (mm)

Displ per drop, 22mm x 1.5m
Displ at failure, 22mm x 1.5m
Displ per drop, 22mm x 0.9m
Displ per drop, 20mm x 1.5m
Displ per drop, 20mm x 0.9m
Displ at failure, 20mm x 1.5m

Max IE = 49 kJ for 20 mm bolt
Max IE = 56 kJ for 22 mm bolt

D-Bolt

Roofex

Technical Information Data Sheets

- Developed as part of a project funded in part by the Workplace Safety and Insurance Board (WSIB) of Ontario in 2007
- Supported by Workplace Safety North (WSN) Ground Control technical advisory committee
- Data sheets were updated in 2012
- Available on WSN website
- Data used from:
  - Literature
  - Supplier
  - CanmetMINING testing results
An example of a data sheet

TECHNICAL INFORMATION DATA SHEET NO.5A - MODIFIED CONE BOLT MCRB3 (NTC-MANSOUR).

BACKGROUND:
- DESCRIPTION: Smooth bar with threads at collar or plate end, and forged cone and mixing blade at tap anchor end. Resin is used for infilling the hole and anchoring the bolt. The bolt is sometimes coated with grease to facilitate debonding and ease ploughing through the resin.

APPLICATION: For mine openings subject to seismicity and rock bursting.

INSTALLATION: Resin cartridges are first inserted. The bolt is then pushed slowly inside the hole while maintaining a full-speed rotation to ensure a complete mixing of the resin. The face plate and nut are tightened once the resin has set.

ADVANTAGES: For both static and passive loading conditions. Behaviour similar to the standard mechanical bolt behaviour under static loading conditions. The bolt will yield and plough through the resin under dynamic loading, thus absorbing the retained energy.

LIMITATIONS: Proper resin mixing is critical.

REFERENCE: Mansour Mining 2011.

<table>
<thead>
<tr>
<th>PROPERTY</th>
<th>SI Test (N)</th>
<th>Laboratory-Static (N)</th>
<th>Laboratory-Dynamic (N)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Steel Grade</td>
<td>C6055 Mod</td>
<td>C6055 Mod</td>
<td>C6055 Mod</td>
</tr>
<tr>
<td>Bonded Yld/Tensile</td>
<td>448,689</td>
<td>448,689</td>
<td>448,689</td>
</tr>
<tr>
<td>Bolt Cone Diameter (mm)</td>
<td>17.2/22.5</td>
<td>17.2/23.1</td>
<td>17.2/23.1</td>
</tr>
<tr>
<td>Hole Diameter (mm)</td>
<td>3.5</td>
<td>3.6</td>
<td>3.4</td>
</tr>
<tr>
<td>Bolt Length (mm)</td>
<td>2230</td>
<td>2235</td>
<td>1635</td>
</tr>
<tr>
<td>Yield Load (kN)</td>
<td>112 ± 3</td>
<td>114 ± 3</td>
<td>N/A</td>
</tr>
<tr>
<td>Maximum Load (kN)</td>
<td>168 ± 4</td>
<td>173 ± 3</td>
<td>200 ± 59</td>
</tr>
<tr>
<td>Dynamic Average Load (kN)</td>
<td>N/A</td>
<td>N/A</td>
<td>134 ± 16</td>
</tr>
<tr>
<td>Displacement (mm)</td>
<td>150 (nominal)</td>
<td>243 ± 37</td>
<td>160 ± 72</td>
</tr>
<tr>
<td>Steel Elongation (%)</td>
<td>N/A</td>
<td>9 ± 1</td>
<td>1.8 ± 1.3</td>
</tr>
<tr>
<td>Stiffness (kN/m)</td>
<td>19 ± 3</td>
<td>29 ± 2</td>
<td>17.6</td>
</tr>
<tr>
<td>Plate Work (kJ)</td>
<td>23 ± 1</td>
<td>36 ± 5</td>
<td>16 ± 1 (impact E = 16 kJ; v = 2.4 m/s)</td>
</tr>
</tbody>
</table>

TECHNICAL INFORMATION DATA SHEET NO.5A - MODIFIED CONE BOLT MCRB3 (NTC-MANSOUR) (CONTINUED).

ILLUSTRATION:

© 2004 Mansour Mining

MCRB3 - Laboratory and In Situ Static Tests


MCRB3 - Dynamic Test

Dynamic Testing of Friction Bolts

- Development of high-strength concrete
  - Results presented at Ground Support 2008

Swellex – Pull tests in concrete

Six samples reached maximum anchorage capacity

Theoretical pullout resistance for pump pressure @ 300 bars and hole diameter @ 38 mm
Swellex - Dynamic tests

First series: only ploughing
Second series: 10% elongation achieved, but no failure

Dynamic Testing of Friction Bolts

- Development of high-strength concrete
  - Results presented at Ground Support 2008
- In-situ pull tests realized at CanmetMINING Experimental mine
Dynamic Testing of Friction Bolts

- Development of high-strength concrete
  - Results presented at Ground Support 2008
- In-situ pull tests realized at CanmetMINING Experimental mine
- Laboratory pull tests with various concrete / aggregates combinations
Dynamic Testing of Friction Bolts

- Development of high-strength concrete
  - Results presented at Ground Support 2008
- In-situ pull tests realized at CanmetMINING Experimental mine
- Laboratory pull tests with various concrete / aggregates combinations
- Laboratory pull tests with granite cores
Pull Test Results – Rock Core

Preliminary Results – Friction Bolts

Impact Energy = 15 kJ
Impact velocity = 5 m/s
Split tube – 1.2m anchor
Static Testing of Surface Support

Effect of fiber types on shotcrete performance
Dynamic Testing of Surface Support

- Internal research project to define testing protocol

Panel 1 - Drop 1
Wt = 37.8 kg; Ht = 1.3 m
0.48 kJ; 5 m/s

Mechanical Testing of Rock Bolts

- Tension Test using ASTM A370 Standard Test Methods
- Full-size Mechanical, Rebar and Expandable Bolts
- Standard Tension Test Specimen Machined from Bolts
Tension Testing of Rock Bolts and Accessories

Tension Testing of Expandable Bolts
Longitudinal Strip Test specimen Machined from Expandable Bolt

Future Work

- Installation, commissioning and upgrading the NTC equipment
- Development of testing protocols for:
  -树脂/密实剂安装
  -摩擦螺栓
    - 螺栓/附件装配
  -表面支撑
- Upgrade the machine to test bolt/surface support assembly
- Prepare and update technical data sheets
Project Linkages

Merci!

Thank you!