Use of Polyurethane Resin to Mitigate Rockfall

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Overview

- What is PUR
- Field Testing of PUR
- Excavation of PUR Test Site
- Observations after Excavation
What is PUR

- Polyurethane Resin
  - “Rock Gluing”
- Successfully used in underground coal mines since the 1960’s
- Popular and cost effective alternative to traditional mining roof control technologies
- Used to Stabilize roadways, concrete structures, historic buildings, and bridges
Polyurethane Resins and Epoxy Grouts

- Densities range from 3 to 70 PCF
- Compressive (Tensile) Strength: 10 to 20,000 PSI
- Variable expansive properties
- Quick cure time – minutes to hours
Types

Polyurethane (PU)
- Commonly used in void filling
- Hydrophilic - Reacts and will foam in the presence of water
- Expands 25 to 3,000%
- Elongates 10 to 500%
- Shear Strength lowers with expansion
- Single stage
- Potential to Shrink
Types

Polyurethane Resin (PUR)
- Commonly used in “Rock Gluing”
- Hydrophilic or Hydrophobic
- Less likely to react with water
- Has some expansive properties
- Greater Shear Strength and density
- Less likely to Shrink
- Two Stage
Types

- Epoxy Grouts
  - Economic replacement for grout in low access areas
  - True Hydrophobic
  - No Shrink or Swell
  - Low viscosity → higher pressures to place
    - Have to displace water
  - Maintains strength in presence of water
  - Two Stage
<table>
<thead>
<tr>
<th>Property</th>
<th>Polyurethane (PU)</th>
<th>Polyurethane Resin (PUR)</th>
<th>Epoxy (EP)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Component Mixing</td>
<td>One-Stage</td>
<td>Two-Stage</td>
<td>Two-Stage</td>
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<tr>
<td>Injection Type</td>
<td>Foam/Gels/Grout</td>
<td>Grout</td>
<td>Grout</td>
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<tr>
<td>Injection Pressures</td>
<td>Low to High (100 to 3,000 psi)</td>
<td>Low to High (10 to 3,000 psi)</td>
<td>Low to Medium (30 to 800 psi)</td>
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<tr>
<td>Density</td>
<td>Low to Medium (3 to 50 pcf)</td>
<td>Medium to High (20 to 70 pcf)</td>
<td>Low to High (5 to 60 pcf)</td>
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<tr>
<td>Compressive/Tensile</td>
<td>Low (10 to 500 psi)</td>
<td>Low to High (15 to 20,000 psi)</td>
<td>Medium to High (5,000 to 20,000 psi)</td>
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<td>Strength</td>
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<td>Very Low to High</td>
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<tr>
<td>Viscosity</td>
<td>Low to Medium</td>
<td>Low to High</td>
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<tr>
<td>Water Interactions</td>
<td>Hydrophilic</td>
<td>Hydrophilic/Hydrophobic</td>
<td>Hydrophobic</td>
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<tr>
<td>Expansion/Elongation</td>
<td>Varies (10% to 3,000%)</td>
<td>Varies (10% to 3,000%)</td>
<td>Minimal</td>
</tr>
<tr>
<td>Shrinkage</td>
<td>Varies (1% to 10%)</td>
<td>Varies (0% to 3%)</td>
<td>Minimal</td>
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<tr>
<td>Relative Product Cost</td>
<td>Low</td>
<td>Mid to High</td>
<td>High</td>
</tr>
</tbody>
</table>
Experimental Field Testing in Tennessee

- Three sites
- All I-75
- All highly fractured sandstone
- Injection started on November 13, 2013
  - Very cold
Site 1 – I75 South Bound MM 152
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Site 1 – I75 South Bound MM 152

Contact with Water
Clean up

- Easy while still warm and pliable
- Much harder after it cures
Site 1 – I75 South Bound MM 152
Site 2 – I75 North Bound MM 147.5
Site 2 – I75 North Bound MM 147.5

11/15/2013
Site 3 – I75 North Bound MM 149
Site 3 – I75 North Bound MM 149
Back to Site 2 - Excavation
Blasting
Blasting
After Blasting
After Blasting
What did we learn?
What did we learn?
What did we learn?
What did we learn?

Over 4 feet long
What did we learn?

Up to 2 feet wide

Over 1 foot thick
What did we learn?
Would we use it again?
Questions?