Shotcrete Activities in the Czech Republic

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Czech WG12 leader
D2 Consult
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   - Fibre reinforced shotcrete
   - Plain secondary lining
   - Shotcrete nozzlemen certification
1. NATM tunnelling in the Czech Republic
# Completed NATM Road Tunnels

<table>
<thead>
<tr>
<th>Tunnel</th>
<th>Total length of driven sections (m)</th>
<th>Profile (m²)</th>
<th>Overburden (m)</th>
<th>Deformations (mm)</th>
<th>Geology</th>
<th>Construct. period</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hřebeč</td>
<td>275</td>
<td>160</td>
<td>40</td>
<td>40</td>
<td>Rock</td>
<td>1995 - 1996</td>
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<tr>
<td>Valík</td>
<td>2 x 200</td>
<td>330</td>
<td>16</td>
<td>15</td>
<td>Rock</td>
<td>2004 - 2005</td>
</tr>
<tr>
<td>Panenská</td>
<td>2 x 2000</td>
<td>90</td>
<td>70</td>
<td>15</td>
<td>Rock</td>
<td>2003 - 2005</td>
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<tr>
<td>Liboucheč</td>
<td>2 x 500</td>
<td>90</td>
<td>30</td>
<td>7</td>
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<tr>
<td>Klimkovice</td>
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<td>20</td>
<td>Rock</td>
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<tr>
<td>Pisárecký</td>
<td>2 x 300</td>
<td>95</td>
<td>35</td>
<td>20</td>
<td>Rock</td>
<td>1995 - 1997</td>
</tr>
<tr>
<td>Mrázovka</td>
<td>2 x 1000</td>
<td>140 - 350</td>
<td>60</td>
<td></td>
<td>Rock</td>
<td>1999 - 2004</td>
</tr>
<tr>
<td>TOTAL</td>
<td>10 km</td>
<td>100 - 120 m²</td>
<td>20 - 60 m</td>
<td>20 mm</td>
<td>Rock</td>
<td></td>
</tr>
</tbody>
</table>

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Czech NATM Highway Tunnels (recently completed)
## Completed NATM Railway Tunnels

<table>
<thead>
<tr>
<th>Tunnel</th>
<th>Total length of driven sections (m)</th>
<th>Profile (m²)</th>
<th>Overburden (m)</th>
<th>Deformations (mm)</th>
<th>Geology</th>
<th>Construct. period</th>
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<tbody>
<tr>
<td>Vepřek</td>
<td>272</td>
<td>112</td>
<td>30</td>
<td>20</td>
<td>Rock</td>
<td>2002 - 2003</td>
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<tr>
<td>Krasíkovský</td>
<td>1035</td>
<td>124</td>
<td>15</td>
<td>10</td>
<td>Rock</td>
<td>2002 - 2003</td>
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<tr>
<td>Tatenický</td>
<td>85</td>
<td>112</td>
<td>25</td>
<td>15</td>
<td>Rock</td>
<td>2002 - 2003</td>
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<tr>
<td>Malá Huba</td>
<td>300</td>
<td>117</td>
<td>20</td>
<td>15</td>
<td>Rock</td>
<td>2003 - 2004</td>
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<td>Hněvkovský I.</td>
<td>130</td>
<td>117</td>
<td>15</td>
<td>15</td>
<td>Rock</td>
<td>2004 - 2005</td>
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<tr>
<td>Hněvkovský II.</td>
<td>432</td>
<td>104</td>
<td>15</td>
<td>15</td>
<td>Rock</td>
<td>2004 - 2005</td>
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<tr>
<td>Nové spojení</td>
<td>2 x 1200</td>
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<td>50</td>
<td>15</td>
<td>Rock</td>
<td>2005 - 2006</td>
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<tr>
<td>Březno</td>
<td>1500</td>
<td>72</td>
<td>30</td>
<td></td>
<td>Soft ground</td>
<td>2002 - 2007</td>
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<tr>
<td><strong>CELKEM</strong></td>
<td><strong>6 km</strong></td>
<td><strong>110 m²</strong></td>
<td><strong>20 – 50 m</strong></td>
<td><strong>15 mm</strong></td>
<td><strong>Rock</strong></td>
<td></td>
</tr>
</tbody>
</table>

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Typical Czech NATM Tunnel

Tunnel overburden: 20 – 60 meters

Tunnel length: 500 – 1500 m

Tunnel profile: 100 – 120 m²

Geology: Rock
Typical Czech NATM Road Tunnel
Two-lane twin tube
Czech NATM Road Tunnels
Typical Czech NATM Railway Tunnel
Double track (single bore)
Czech NATM Railway Tunnels
### Planned Road Tunnels (2006 – 2015)

<table>
<thead>
<tr>
<th>Tunnel</th>
<th>Total length of driven sections (m)</th>
<th>Profile (m²)</th>
<th>Overburden (m)</th>
<th>Geology</th>
<th>Construction period</th>
</tr>
</thead>
<tbody>
<tr>
<td>SOKP 513</td>
<td>2 x 1900</td>
<td>110 - 160</td>
<td>50</td>
<td>Rock</td>
<td>2006 - 2008</td>
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<tr>
<td>SOKP 514</td>
<td>2 x 1650</td>
<td>110 - 160</td>
<td>50</td>
<td>Rock</td>
<td>2006 - 2008</td>
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<tr>
<td>SOKP 518</td>
<td>2 x 400</td>
<td>100</td>
<td>10</td>
<td>Rock</td>
<td>2008 - 2012</td>
</tr>
<tr>
<td>MO Myslbek</td>
<td>2 x 1000</td>
<td>160</td>
<td>15</td>
<td>Rock</td>
<td>2008 - 2015</td>
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<tr>
<td>MO Blanka</td>
<td>2 x 2500</td>
<td>110 - 160</td>
<td>40</td>
<td>Rock</td>
<td>2008 - 2015</td>
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<tr>
<td>MO Bílá skála</td>
<td>2 x 2000</td>
<td>110</td>
<td>50</td>
<td>Rock</td>
<td>2008 - 2015</td>
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<tr>
<td>MO other</td>
<td>2 x 2000</td>
<td>110</td>
<td>30</td>
<td>Rock</td>
<td>2008 - 2015</td>
</tr>
<tr>
<td>Radlická rad.</td>
<td>2 x 2000</td>
<td>110 - 160</td>
<td>70</td>
<td>Rock</td>
<td>2008 - 2015</td>
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<tr>
<td>Dobrovského</td>
<td>2 x 1000</td>
<td>125</td>
<td>25</td>
<td>Soft ground</td>
<td>2006 - 2009</td>
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<tr>
<td>D8 Radejčín</td>
<td>2 x 600</td>
<td>120</td>
<td>50</td>
<td>Rock</td>
<td>2010 - 2012</td>
</tr>
<tr>
<td>D8 Prackovice</td>
<td>2 x 300</td>
<td>120</td>
<td>50</td>
<td>Rock</td>
<td>2010 - 2012</td>
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<tr>
<td>D3</td>
<td>2 x 2000</td>
<td>100</td>
<td>50</td>
<td>Rock</td>
<td>2010 - 2015</td>
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<tr>
<td>R11</td>
<td>2 x 2000</td>
<td>?</td>
<td>100</td>
<td>Rock</td>
<td>2010 - 2015</td>
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<tr>
<td><strong>TOTAL</strong></td>
<td><strong>30 km</strong></td>
<td><strong>100 – 160 m²</strong></td>
<td><strong>20 – 60 m</strong></td>
<td><strong>Rock</strong></td>
<td><strong>2006 - 2015</strong></td>
</tr>
</tbody>
</table>
### Planned Railway Tunnels (2008 – 2015)

<table>
<thead>
<tr>
<th>Tunnel</th>
<th>Total lenght of driven sections (m)</th>
<th>Profile (m²)</th>
<th>Overburden (m)</th>
<th>Geology</th>
<th>Construction period</th>
</tr>
</thead>
<tbody>
<tr>
<td>3rd railway corridor</td>
<td>Prague – Pilsner – Cheb - Germany</td>
<td></td>
<td></td>
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<tr>
<td>Prague - Beroun</td>
<td>2 x 25000</td>
<td>do 110</td>
<td>180</td>
<td>Rock</td>
<td>2011 -2016</td>
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<tr>
<td>Homolka</td>
<td>2 x 4000</td>
<td>110 až 124</td>
<td>70</td>
<td>Rock</td>
<td>2008 -2013</td>
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<tr>
<td>Cheb</td>
<td>500</td>
<td>65</td>
<td>15</td>
<td>Soft ground</td>
<td>2008 -2013</td>
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<tr>
<td>4th railway corridor</td>
<td>Prague – Tábor – Czech Budwaiser - Austria</td>
<td></td>
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<tr>
<td>Tomický</td>
<td>300</td>
<td>100</td>
<td>25</td>
<td>Rock</td>
<td>after 2010</td>
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<tr>
<td>Zahradnický</td>
<td>1000</td>
<td>100</td>
<td>50</td>
<td>Rock</td>
<td>after 2010</td>
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<tr>
<td>Olbramovický</td>
<td>500</td>
<td>100</td>
<td>20</td>
<td>Rock</td>
<td>after 2010</td>
</tr>
<tr>
<td>Votice</td>
<td>600</td>
<td>100</td>
<td>25</td>
<td>Rock</td>
<td>after 2010</td>
</tr>
<tr>
<td>Debořice</td>
<td>600</td>
<td>100</td>
<td>50</td>
<td>Rock</td>
<td>after 2010</td>
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<tr>
<td>Mezno</td>
<td>800</td>
<td>100</td>
<td>20</td>
<td>Rock</td>
<td>after 2010</td>
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<td>Sudoměřice</td>
<td>400</td>
<td>100</td>
<td>20</td>
<td>Rock</td>
<td>after 2010</td>
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<td>Zvěrotice</td>
<td>372</td>
<td>100</td>
<td>6</td>
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<td>Sedlčany</td>
<td>300</td>
<td>100</td>
<td>5</td>
<td></td>
<td></td>
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<tr>
<td>Janovský</td>
<td>876</td>
<td>100</td>
<td>11</td>
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<td></td>
</tr>
<tr>
<td>Hosiín</td>
<td>1500</td>
<td>100</td>
<td>50</td>
<td>Various</td>
<td>after 2014</td>
</tr>
<tr>
<td>Nemanice</td>
<td>2300</td>
<td>100</td>
<td>60</td>
<td>Rock</td>
<td>after 2014</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td>70 km</td>
<td>100 m²</td>
<td>20 - 60</td>
<td>Rock</td>
<td>after 2010</td>
</tr>
</tbody>
</table>

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Prague – Beroun
25km long high-speed railway tunnel

- Two tubes + XP
- Speed up to 300kph
- Majority TBM
- Partly NATM

Expected construction: 2011 - 2016

- Prague – bifurcation
  (about 9km of NATM)
NATM Tunnelling in the Czech Republic

+ 

NATM Technology (basic elements, design and construction)
Skills of labours (i.e. nozzlemen), quality of primary shotcrete lining
Geomonitoring (GTM)
Machinery optimalisation
Tunnel functionality, durability

- 

Conservative design, resistance against new methods (permanent SCL, fibre reinforced SCL, etc.)
Excavation optimalisation (based on monitoring, geology, etc.)
Construction management – competencies, involvement of designer, risk management
Construction cost

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2. Shotcrete Trends in the Czech Republic
Steel Fibres Reinforced Shotcrete

Plugs for underground gas reservoir Pribram

Number of plugs: 4  
Length of one plug: 10 m  
Total volume: 620,000 m³  
Gas pressure: 2.0 – 9.5 (12.5) MPa  
Gas capacity: 55 mil. m³ (82 mil. m³)  
Overburden: 1000m  
Fibre dosage: 90kg/m³  
Shotcrete strength: 40MPa  
Completed: 1998  
Required shotcrete watertightness was reached (pressure tests)
Plugs for underground gas reservoir
Pribram

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Permanent Sprayed Concrete Lining

Cable tunnels in Prague

- Geology: sands, gravels
- Support: grouted columns (grouted in advance from face)
- Varying tunnel profile
- Length of columns: 9.25m
- Primary lining: SCL
- No sheet membrane
- Secondary lining:
  - Invert: cast concrete
  - Vault: sprayed concrete
Cable tunnels in Prague

Watertightness:

- Xypex layer (crystallic material)
- Shotcrete composition
- Hydrophilic gaskets
Permanent SCL – Motol adit

- Completed: 2007
- Primary lining: SCL
- No sheet membrane
- Secondary lining:
  - Invert: cast concrete
  - Vault: sprayed concrete

Watertightness:
- Xypex layer (crystalline material)
- Shotcrete composition
- Hydrophilic gaskets
Sprayed Membranes

Prague Metro

- Application: 2005 (first in CR)
- Reason: difficult geometry
- Structure: pumping station
- Material: Masterseal 345
- Sprayed area: 750 m²
- Consumption: 3000 kg
- Good bond to sheet membrane
- Training of local contractors

- Problem: dust
Prague Metro - Sprayed Membranes

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Plain in-situ cast concrete for secondary lining

Liboucheч Tunnel

- 2 x 2 lanes highway tunnel
- Length: 0.5km
- Secondary lining reinforced only in areas of portals and XP
- Allowed cracks: max. 0.8mm
- Calculation: Non-linear
- Steel weight reduction from original 700t to 150t
- Tunnel was opened in 2006
Libouhečec secondary lining (reinforcement scheme)
Certification of Shotcrete Nozzlemen

Documents for procedure

- Basic document about certification (reasons, examining board, management)

- Manual about SCL application (theoretical and practical information for labour)

- Forms for testing

- Certificates

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Programme of Certification

– Education
  • Sprayed concrete (composition, application, etc.)
  • Machinery (operation, maintainance, etc.)

– Practical tests (60%)
  • Tunnel lining spraying (top heading)
  • Test panels spraying

– Theoretical tests (40%)

– Evaluation (more than 70% required)
Certification of Nozzlemen

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Conclusion:

1. **NATM tunnelling in the Czech Republic**
   - NATM – prevailing tunnelling method
   - Many ongoing and proposed NATM projects (highways, railways, utility tunnels, etc.)
   - Good experience with NATM
   - Czech sprayed concrete guidelines were published in 2003 (WG12)

2. **Shotcrete trends in the Czech Republic**
   - Conservative environment (resistance against new methods)
   - First applications of:
     - permanent shotcrete lining
     - sprayed membranes
     - fibre reinforced shotcrete
     - plain secondary lining
   - Shotcrete nozzlemen certification started in 2006 (WG12)
THANKS FOR YOUR ATTENTION