ROADHEADER IN TUNNELING
TODAY’S STATE-OF-THE-ART-ROADHEADER
Sandvik’s objective is zero harm to our people, the environment we work in, our customers and our suppliers.
We’ve always been committed to conducting business with high integrity and in a legal and ethical manner. We embrace our corporate responsibility to combat corruption.
MECHANICAL TUNNEL EXCAVATION

- Part face excavation
- Hard (stable) rock
- Soft (lose) rock
- Full face excavation

Mechanical Tunnel Excavation
TUNNELING SHORT COURSE 2016

CONTENT

• Selection criteria for Excavation method
• Parameter on Roadheader Cuttability
• Current Roadheader technology
• Roadheader projects
SELECTION CRITERIA FOR EXCAVATION METHOD

ROCK

PROJECT

ENVIRONMENT

Drill & Blast

Shield Machines

Roadheaders

Excavator Attachments

Hard rock TBM’s

Mechanical Excavation with Breaker / Splitter

Compressive Strength

Stability / Fracturing
SELECTION CRITERIA FOR EXCAVATION METHOD

EXAMPLES – ROADHEADER SELECTION

• Complex geology
• Free access to the face
• Ability for partial face excavation
• Gentle excavation
• Not sensitive against squeezing rock
• High cutting performance in soft and medium hard rock (up to 130 m³/NCH)
SELECTION CRITERIA FOR EXCAVATION METHOD

EXAMPLES – ROADHEADER SELECTION

• Flexible system – profile, alignment
• Accurate profiling – less over break, less concrete cost
• Low primary investment
• Fast mobilization
PARAMETER FOR ROADHEADER CUTTABILITY

REPRESENTATIVE ROCK SAMPLING

Batching Card for Sample Identification
PARAMETER FOR ROADHEADER CUTTABILITY

UNCONFINED COMPRESSIVE STRENGTH TESTING

• Determination of: $\sigma_c, E_{stat}, E_{sec}, \varepsilon, W_f$

• Standard specimen:
  - $D = 50 \text{ mm} \pm 10\%$
  - $H = D \pm 10\%$

• Load:
  - $F = 10 \text{ kN/s}$
PARAMETER FOR ROADHEADER CUTTABILITY

BRAZILIAN TENSILE STRENGTH TESTING

• Determination of: $\sigma_i$
• Standard specimen:
  – $D = 50 \text{ mm} \pm 10 \%$
  – $H = D/2 \pm 10 \%$
• Load:
  – $F = 10 \text{ kN/s}$
PARAMETER FOR ROADHEADER CUTTABILITY

CERCHAR ABRASIVITY INDEX (CAI) TESTING

• Standard Test Pick Hardness: HRC = 54 - 56
• Optional Test Pick Hardness: HRC = 40 - 42
• Steel Type: Silver Steel 115CrV3 (DIN)
• According to
  - 1.2210 Material Number (DIN EN ISO 4597)
  - 107CrV3 KU in Italy (UNI)
  - F.5125 (120CrV) in Spain (UNE)
  - 11ChF in Russia (GOST)
  - L 2 in USA (AISI)
PARAMETER FOR ROADHEADER CUTTABILTY

CERCHAR ABRASIVITY INDEX (CAI) TESTING

• 10 mm in 1 second over rough surface
• Load: $F = 70$ N
• $CAI = 10 \times d$ [mm]
PARAMETER FOR ROADHEADER CUTTABILITY

HOW TO ASSESS NCR FOR INTACT ROCK

- UCS = 100 MPa
- UCS:BTS = 8 to 15
  - → Normal rock
Technical limit defined by machine

Economical limit defined by operation
PARAMETER FOR ROADHEADER CUTTABILITY

HOW TO ASSESS SPC

Specific Pick Consumption (SPC) for Low Speed Cutting with Transverse Cutterhead and 22 mm TC Diameter Picks of High Quality

Uniaxial Compressive Strength [MPa]

Specific Pick Consumption (SPC) for Low Speed Cutting with Transverse Cutterhead and 22 mm TC Diameter Picks of High Quality

Effective minimum specific pick consumption: 0.005

Uniaxial Compressive Strength [MPa]
PARAMETER FOR ROADHEADER CUTTABILITY

OPERATING LIMITS DEFINED BY SPC

Technical limit defined by machine & tools
Economical limit defined by operation
PARAMETER FOR ROADHEADER CUTTABILITY

INFLUENCE ON ROCK MASS PARAMETERS
PARAMETER FOR ROADHEADER CUTTABILITY

PRINCIPLES OF ROCK MASS INFLUENCE

Strength

Conditions

Orientation

Block size

0.3 m

0.5 m

0.3 m
### ROCK MASS CUTTABILITY RATING (RMCR) SYSTEM

#### Rating of uniaxial compressive strength

<table>
<thead>
<tr>
<th>UCS [MPa]</th>
<th>Rating</th>
<th>Block size [m³]</th>
<th>Rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 0,01</td>
<td>1</td>
<td>&lt; 0,01</td>
<td>1</td>
</tr>
<tr>
<td>0,01 - 0,03</td>
<td>3</td>
<td>0,01 - 0,03</td>
<td>3</td>
</tr>
<tr>
<td>0,03 - 0,06</td>
<td>5</td>
<td>0,06 - 0,1</td>
<td>8</td>
</tr>
<tr>
<td>0,1 - 0,3</td>
<td>10</td>
<td>0,3 - 0,6</td>
<td>16</td>
</tr>
<tr>
<td>&gt; 0,6</td>
<td>20</td>
<td>&gt; 0,6</td>
<td>20</td>
</tr>
</tbody>
</table>

#### Surface Aperture/Influence on cuttability

<table>
<thead>
<tr>
<th>Surface</th>
<th>Aperture</th>
<th>Wall/Fill</th>
<th>Rating</th>
<th>Influence on cuttability</th>
<th>Rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>rough</td>
<td>closed</td>
<td>hard, dry</td>
<td>30</td>
<td>very favorable</td>
<td>-12</td>
</tr>
<tr>
<td>slightly rough</td>
<td>&lt; 1 mm</td>
<td>hard, dry</td>
<td>20</td>
<td>favorable</td>
<td>-10</td>
</tr>
<tr>
<td>slightly rough</td>
<td>&lt; 1 mm</td>
<td>soft, dry</td>
<td>10</td>
<td>fair (and if block size &lt;0,03m³)</td>
<td>-5</td>
</tr>
<tr>
<td>smooth</td>
<td>1 - 5 mm</td>
<td>soft, damp</td>
<td>5</td>
<td>unfavorable</td>
<td>-3</td>
</tr>
<tr>
<td>very smooth</td>
<td>&gt; 5 mm</td>
<td>soft, damp to wet</td>
<td>0</td>
<td>very unfavorable</td>
<td>0</td>
</tr>
</tbody>
</table>
PARAMETER FOR ROADHEADER CUTTABILITY

HOW TO ASSESS NCR FOR ROCK MASS

Evaluation of Rock Mass Influence on NCR
(Low cutting speed - 1.4 m/s)

$\frac{\text{NCR}_{\text{eff}}}{\text{NCR}_{\text{theor}}} = 45,553 \cdot \text{RMCR}^{-0.9821}$

$R^2 = 0.9332$

$\text{RMCR} = 30 \Rightarrow \text{increase in NCR} \sim 60\%$

$\text{NCR}_{\text{eff}}/\text{NCR}_{\text{theor}} = 45,553 \cdot \text{RMCR}^{-0.9821}$

$R^2 = 0.9332$
PARAMETER FOR ROADHEADER CUTTABILITY

HOW ROCK MASS IMPACT ROADHEADER CUTTABILITY

Net Cutting Rate for MT620/720 (300 kW installed cutter head power) equipped with Cutter Head 105-G 72 and 25 mm TC Diameter Picks according to Uniaxial Compressive Strength of Intact Rock with Normal Fracturing Behavior for Different Cross Sections

$\text{RMCR} = 30$

Rock mass favorable for cutting can make an uneconomical or critical operation economical!!!
PARAMETER FOR ROADHEADER CUTTABILITY

ROCK MASS CUTABILITY RATING (RMCR) SYSTEM

<table>
<thead>
<tr>
<th>RMCR</th>
<th>Influence on cuttability by roadheaders</th>
</tr>
</thead>
<tbody>
<tr>
<td>40 - 60</td>
<td>no to little influence</td>
</tr>
<tr>
<td>25 - 40</td>
<td>moderate influence</td>
</tr>
<tr>
<td>15 - 25</td>
<td>considerable influence</td>
</tr>
<tr>
<td>10 - 15</td>
<td>high influence</td>
</tr>
<tr>
<td>&lt; 10</td>
<td>dominating influence</td>
</tr>
</tbody>
</table>
CURRENT ROADHEADER TECHNOLOGY

MT720 ROADHEADER WITH ICUTROC TECHNOLOGY

- **MT720 Tunnel Miner**
  - Heavy-duty Roadheader for tunneling in “hard rock conditions”
  - Especially designed for large cross sections

- **Key Technical data**
  - Weight: ~135 t
  - Cutter motor power: 300 kW
  - Large cutting area: ~61 m²
  - Fully PLC controlled
  - ICUTROC technology
CURRENT ROADHEADER TECHNOLOGY

MT720 ROADHEADER WITH ICUTROC TECHNOLOGY

- Highly efficient stabilized CUTTING SYSTEM
CURRENT ROADHEADER TECHNOLOGY

MT720 ROADHEADER

- Different cabin designs (FOPS)
- Roadheader without cabin
- Profile monitoring (optional)
- Guidance system (optional)
CURRENT ROADHEADER TECHNOLOGY

MT720 ROADHEADER WITH ICUTROC TECHNOLOGY

• Keeping records with DATALOGGING SYSTEM

• DRRS – Data Recording & Reporting System
ROADHEADER PROJECTS

ROADHEADERS WORKING IN CONSTRUCTION PROJECTS

- **Projects in Sochi for 2014 Olympics**
  - 2010 until 2012/13
    - 2 x ATM75 and 2 x MR360 and 1 x MT360
    - 4 x MT520
    - 3 x ATM105 and 1 x AHM105 and 2 x MT720

- **Projects in Europe**
  - 2015/16 1 x MT720 @ Pforzheim, Germany
  - 2013/14 1 x MT720 @ Bormio, Italy
  - 2012/13 1 x MT520 @ Polidano, Malta
  - 2011/12 1 x MT720 @ Markovec Tunnel
  - 1999/2010 7 x MT720 @ Bilbao, Spain

- **Projects in North America**
  - 2017/18 2 x MT520 @ Peace River Hydro
  - 2013/16 3 x MT720 @ Ottawa Light Rail
  - 2008/10 3 x MT720 @ East Side Access
  - 2007/08 2 x MT720 @ Devil’s Slide
  - 2007/08 1 x MT720 @ Arch
  - 2004/05 1 x MT720 @ Fox River stone
  - 2002/03 2 x MT720 @ Metro Montreal

- **Project in Australia**
  - 2009/10 8 x MT720 @ Airport Link Brisbane, Australia
  - 2016/18 24 x MT720 & MT520 @ NorthConnex and WestConnex Sydney, Australia
ROADHEADER IN TUNNELING

MARKOVEC TUNNEL, SLOVENIA

• Project data
  - 2.2 km double twin tube road tunnel between Koper and Izola (Slovenian Coastline)
  - Residential area at Koper side with overburden of 10-35m
  - 560m in each tube to be excavated by means of Road-Header

• Geologic data
  - Flysch dominated by Marl
  - Interbeds of Sandstone and Calcarenite (UCS up to 200 MPa)
  - Area with shallow overburden weak rock predicted
  - Sandstone layer thickness of 2m
ROADHEADER IN TUNNELING

MARKOVEC TUNNEL, SLOVENIA

- Up to 8 m/d
ROADHEADER IN TUNNELING

ST. LUCIA TUNNEL BORMIO, ITALY

• Project data
  – About 1km single tube road tunnel
  – Bypass of Bormio residential area

• Geological data
  – Quartzitic mica schist
  – Gneiss
  – UCS values between 40 – 200MPa
  – CAI 2,5 – 5
ROADHEADER IN TUNNELING

ST. LUCIA TUNNEL BORMIO, ITALY
ROADHEADER IN TUNNELING

ST. LUCIA TUNNEL BORMIO, ITALY

- ~ 4m/day
ROADHEADER IN TUNNELING

METRO MONTREAL, CANADA

• Project data
  - Metro tunnel
  - Length: ~1.8 km
  - Cross section: ~44 m²

• Geologic data
  - Limestone-shale interbedding, massive crystalline limestone, diabase dikes
  - Average UCS: ~90 MPa
  - Average CAI: ~0.7
  - Very well bedded rock mass
  - Average NCR: ~39 solid m³/nch
  - Average SPC: ~0.1 picks/solid m³
Better advance rate than D&B related to single face operation
ROADHEADER IN TUNNELING

METRO MONTREAL, CANADA

• Visible arguments for Roadheader
ROADHEADER IN TUNNELING

STATION EXCAVATION, EAST SIDE ACCESS

- **Project data**
  - Metro station excavation
  - Launch chamber for TBM
  - Additional auxiliary structures
  - Small to large cross sections

- **Geologic data**
  - Schist (partly gneissic), pegmatite
  - Average UCS: ~80-95 MPa
  - Average CAI: ~3.7-3.8
  - Massive to significantly fractured rock mass
ROADHEADER IN TUNNELING

STATION EXCAVATION, EAST SIDE ACCESS

Average NCR: 17.71 solid m³/h
Average SPC: 1,526 picks/solid m³

ATM105/046 at New York/USA
Net Cutting Rate (NCR) and Specific Pick Consumption (SPC)

Daily NCR  •  Cumulative Average NCR  •  Daily SPC  •  Cumulative Average SPC
ROADHEADER IN TUNNELING

NORTHCONNEX AND WESTCONNEX, AUSTRALIA

• Connecting M1 at Wahroonga to M2 at West Pennant

• Extension work on M4

Total 21 Sandvik Roadheaders (MT720, MT520)
• The ICUTROC technology has proven
  • ... to be an economic alternative for challenging excavation projects
  • ... the ability to deal with harder & sensitive rock condition forming low risk for the Contractor/Owner
  • ... high productivity resulting in low excavation cost