Chemistry, shotcrete and manipulators around the TBM
CIA Seminar Brisbane, July 2009

BASF Construction Chemicals
Lars Langmaack
TBM design vs. geology

3 main types

- Hard rock
- EPB
- Slurry
Sealing the TBM

- Water / foam / polymer / anti-clay-agent
- Tail sealant
- Excluder grease / main bearing sealing grease
Soil Conditioning Foams and Polymers
Soil Changes
With foam

Dry sand & granite chips + Water + Soil conditioning
Injection Points
At the TBM cutterhead
Actual range of EPB use
Weak ground under groundwater pressure

Clay adhesion & clogging
Use foam and anti-clay additives

Silty sands
Use foams

Coarse, frictioned soil
Use foam & polymers

Clay
Silt
Sand
Gravel

Particle size [mm]

0 10 20 30 40 50 60 70 80 90 100

0.001 0.010 0.100 1 10 100

Very coarse, frictioned soil
Use foam & special polymers + fine filler
World’s biggest EPB TBM, MHI
Madrid M30 motorway project, Spain
World’s biggest EPB TBM, S-300
Herrenknecht Madrid M30 motorway project, Spain
Toulouse Metro project
Conditioned soil comparison

Dry excavation

Homogeneous & plastic soil with MEYCO SLF 30 and Rheosoil 211
How do polymers work?

Polymer SLF P2
Effect of structuring polymers

2.5 bar sea water pressure
use of foam

2.5 bar sea water pressure
use of foam & polymer
NAT 2008 San Francisco Short Course
Annulus Grouts

Lars Langmaack, BASF Construction Chemicals
UGC Underground Construction Group
Sealing the TBM

- Water / foam / polymer / anti-clay-agent
- Tail sealant
- Excluder grease / main bearing sealing grease
Why annulus grout is important

- To give early stability as construction occurs
- To prevent heave / flotation of the lining
- To take early load in the build area
- To reduce settlement, especially in non-cohesive soils
- To prevent segmental misalignment and the rupturing of gaskets
- To eliminate / reduce water ingress to avoid secondary injection (costly)
Required Performance of annulus grout

- Good flowability
- Good pumpability over pumping distance
- Workability may be required from 4 - 24 hours
- No bleeding (<1% bleed of free water)
- Anti-washout properties
- Easy to mix and transport
- Easy cleaning of the grout channel (tailskin)
- Durable and no shrinkage
- Economical mix and total economical solution
Annulus grout materials

- Cement
- Fine aggregates
- Water
- PFA (fly ash)
- Limestone dust
- Blast Furnace Slag
- Bentonite
- Colloidal silica
- Admixtures
... here it is!!
'Standard' grouts
## VALSUGANA
### MALTA BACK FILLING

<table>
<thead>
<tr>
<th>Mix</th>
<th>Composizione</th>
</tr>
</thead>
<tbody>
<tr>
<td>CEM II/A-L 42,5R</td>
<td>450 kg/m³</td>
</tr>
<tr>
<td>water</td>
<td>320 l/m³</td>
</tr>
<tr>
<td>sand</td>
<td>1200 kg/m³</td>
</tr>
<tr>
<td>Additivo Superfluidificante</td>
<td></td>
</tr>
<tr>
<td>Glenium 20</td>
<td>2,0 l/m³</td>
</tr>
<tr>
<td>Air entrainer Micro Air 200</td>
<td>3,0 l/m³</td>
</tr>
<tr>
<td>retarder Pozzolith BM</td>
<td>0,4 l/m³</td>
</tr>
<tr>
<td>Marsh cone (13 mm)</td>
<td>38 s</td>
</tr>
<tr>
<td>Bleeding at 3 h</td>
<td>0,0 %</td>
</tr>
<tr>
<td>Open time</td>
<td>5 h</td>
</tr>
<tr>
<td>density</td>
<td>1970 kg/m³</td>
</tr>
</tbody>
</table>
VALSUGANA
MALTA  BACK FILLING
Accelerated grouts
Typical mix design (kg/m³):
Cement : 230-280kg
Bentonite 60kg (Wyoming Bentonite 30kg)
Water: 800-860 kg (wcr approx. 3.5)
Stabilizer: 2.5-3 l/m³ POZZOLITH 89

Added at the injection point: 60-80 kg Sodium Silicate MEYCO FIX GA 10

• Computerized system, the grout pumps starts when the TBM is moving
• Cement/Bentonite solution stable for 24 hours (can be 2-3 days)
• Can be pumped over long distance
• Instant gelling when Component B is added gives early support
**Componenti** | Mix 1 | Mix 2 | Mix 3 |
--- | --- | --- | --- |
CEM IV/B (P) 32,5R | 250 kg/m³ | 260 kg/m³ | 250 kg/m³ |
Fly ash | 580 kg/m³ | --- | 150 kg/m³ |
Calcerous filler | --- | 1000 kg/m³ | --- |
Bentonite | --- | 20 kg/m³ | 30 kg/m³ |
water | 600 l/m³ | 440 l/m³ | 830 l/m³ |
Additivo GLENIUM PF | 2,0 l/m³ | 5,0 l/m³ | --- |
Accelerante MEYCO SA 162 | 42,0 kg/m³ | 22,5 kg/m³ | 30 kg/m³ |
retarder DELVO | 500 g/m³ | 1000 g/m³ | 500 g/m³ |
1h compressive strengh | plastic clay | 0,10 | plastic clay |
24h compressive strengh | 0,20 – 0,40 | > 1,0 | 0,10 |
METRO NAPOLI
BOIACCA BACK FILLING
Pea gravel grouting
<table>
<thead>
<tr>
<th>Mix</th>
<th>Composizione</th>
</tr>
</thead>
<tbody>
<tr>
<td>CEM I 52,5R</td>
<td>1075 kg/m³</td>
</tr>
<tr>
<td>water</td>
<td>620 l/m³</td>
</tr>
<tr>
<td>Additivo Superfluidificante</td>
<td>Rheobuild 561</td>
</tr>
<tr>
<td></td>
<td>6,5 l/m³</td>
</tr>
<tr>
<td>density</td>
<td>1730 kg/m³</td>
</tr>
<tr>
<td>Marsh cone (4,7 mm)</td>
<td>46 s</td>
</tr>
<tr>
<td>Marsh cone after 120 minutes</td>
<td>52 s</td>
</tr>
<tr>
<td>Bleeding at 2 h</td>
<td>4,0 %</td>
</tr>
<tr>
<td>Compressive strength at 28 d</td>
<td>33,0 MPa</td>
</tr>
</tbody>
</table>
Hard rock – Val Viola
MEYCO ABR anti-abrasion and anti-dust technology
Site Example: Guadarrama high speed rail tunnel

- Four hard rock TBM machines
  - diameter: 9.5 m
  - 2 x Herrenknecht
  - 2 x Wirth
- Two TBMs drive from the north, the other two drive from the south
  - total length: 56 km
- Geology:
  - mainly granite, high quartz content
  - 100-200 MPa
  - very high abrasivity
Guadarrama Rock
Abrasivity index

CAI = 5.66

- CAI (Cercher Abrasivity Index)
- 0: not very abrasive
- 1: slightly abrasive
- 2: medium abrasive to abrasive
- 3: very abrasive
- 4: extremely abrasive
- 5: quarsitic

Guadarrama Rock is classified as extremely abrasive.
Guadarrama project, Spain
Situation with only using water

Number of cutters changed typically varied from 5-28 per day

High maintenance cost, lot of down time

Due to the high temperature, cutters can get blocked (failure of bearing seal)

High temperature and high dust level. Time consuming disc cutter change
Use of MEYCO ABR on the TBM
MEYCO ABR 5

Benefits

Without ABR

Disappearance of dust  
longer life time of electronics,  
healthier working conditions

Clean & cool cutters  
easy & quick to change  
no muck clogging

Drastic reduction of cutter temperature (150→70°C)  
no cutter blockage  
15% wear reduction  
reduced TBM downtime

With ABR
Advanced Spraying Equipment
Our Value Proposition to the Market
From wet to dry, from low to high volume spraying, for hand application or robotic spraying, we offer the solution.
Hallandsåsen
Early 90’s

Ring beam plus emergency rigs behind head and possibility to poke through head

Together with Supremas
TBM Installations

Steg Raron, Lötschberg, CH
TBM Installations

Steg Raron, Lötschberg, CH
Twin Spraying Manipulators
together with
MEYCO Supremas
TBM Installations
Alp Transit Project Lötschberg (CH)
TBM Solution Project Steg/Raron (CH)
Wet-mix sprayed concrete application for TBM excavation; the solution from MEYCO® Equipment:

- Two spraying robots mounted on a circular beam structure which can move in the tunneling direction.
- The entire tunnel surface above the invert segment can be sprayed.
- The two spraying robots are each fed individually by a MEYCO® SUPREMA sprayed concrete pump and have an individual concrete logistics line.

Mix design for wet-mix sprayed concrete on the TBM back-up (joint venture MaTrans, Steg/Raron):

<table>
<thead>
<tr>
<th>Component</th>
<th>Percentage</th>
<th>Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aggregates*</td>
<td>0-4 mm %</td>
<td>60</td>
</tr>
<tr>
<td>Aggregates*</td>
<td>4-8 mm %</td>
<td>40</td>
</tr>
<tr>
<td>Cement</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Superplasticizer</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Accelerator</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Silica fume</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Steel fibres</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Juracime CEM I 52.5</td>
<td></td>
<td>425 kg/m³</td>
</tr>
<tr>
<td>Rheobuild® T3</td>
<td></td>
<td>1.2%</td>
</tr>
<tr>
<td>MEYCO® SA170</td>
<td></td>
<td>5-6%</td>
</tr>
<tr>
<td>Microsilica powder</td>
<td></td>
<td>30 kg/m³</td>
</tr>
<tr>
<td>Dramix 85/35</td>
<td></td>
<td>35 kg/m³</td>
</tr>
</tbody>
</table>

*(The aggregates are prepared from crushed tunnel excavation material)*
TBM Installations

Bedio Faido

Split pumping/dosing system

Spraying head
Maurice LeMaire, France, Herrenknecht TBM
Special manipulator mounted on central pipe

Mixdesign
Aggregates 0/4mm: 800kg
4/10mm: 950kg
Cement: 420kg
Water: 200 l
Superplasticiser: 1 l
TBM Installations

Visp, Switzerland
TBM Installations

Liaoning, China
Complete spraying systems including modified manipulators and Supremas
Complete spraying systems as consisting of:
• Concrete pump
• Accelerator dosing system
• Delivery and nozzle system
• Spraying manipulator

The solution:
• MEYCO delivers engineering, manufacture, commissioning and training as well as complete spares service.
• Repairs and reconditioning of the complete system when the project is finished.
Spraying machine (pump) MEYCO Suprema, either with 30 m³/h or 20 m³/h theoretical capacity

Computer controlled pumping and dosing systems for very low-pulsation pumping and accurate dosing.

Can be mounted as a unit or (normally) split
Tailor-made solutions for TBMs

Dosing unit can also be seperately mounted

Dosing unit for liquid additives. Integrated proportioning unit, infinitely variable controlled through the PLC system, fully integrated into the flow rate adjustment.

Setting of the desired values by using keyboard.
Tailor-made solutions for TBMs

Adjustment, once set, the desired amount of additive will be held constant through the interaction of:
- flowmeter
- frequency converter
- controller

The additive pressure is secured by a pressure switch.

Suitable for new generation alkali-free accelerators.
A project getting underway is West Qinling, China where twin rail tunnels of 10.3 m diameter are to be bored.

Each TBM will be equipped with ring-beam mounted dual spraying manipulators with a spraying area length of 8 metres. The spraying heads will run on carriages along a lattice beam.
4 MEYCO Suprema 30s specially constructed to be accommodated perfectly within the TBM back-up rig.

MEYCO will also provide installation expertise and local after-sales support services for the spraying operations.
MEYCO designs and constructs tailor-made spraying systems for integration within TBMs.

MEYCO cooperates worldwide with companies such as Herrenknecht and Robbins on many special projects, the Jinping HEPP for example.
MEYCO can also plan and be on site to install the delivery system which is often quite complex.

Preparation and planning are important as often hoses, pipes and bends need to have special lengths or radius.
• Commissioning
• Repairs
• Training
• Consulting (wear & spare parts etc.)
MEYCO products conform to EU standards

MEYCO is certified
ISO 9001 + ISO 14001

Visit us at http://www.meyco.basf.com