Technical Meeting
HKIE Geotechnical Dev.

Application of Chemical Grouts to Tunnel Repair – Latest Technology

Vincent Chien / Thorsten Tatzki

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The Speaker

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C-Eng, Working for Minova in Taiwan

Thorsten Tatzki
C-Eng, head office in Germany
Chemical grouts are new, the tasks are old!

Tunnel repairing about 1910
Blisworth Tunnel / England
Our topics for today:

- Crack repairing
- Damaging situation after concreting
- Injection hoses
- Injection plates
- Repairing different joint types
- Overview and costs
Who is Minova-CT?

Our traditional roots are based in the German coal mining industry.

We have a long history:

- 2004 Minova CarboTech GmbH
- 2000 CarboTech Fosroc ...
- 1985 CarboTech Berg und Tunnelbau ...
- 1968 Deutsche Bergbauforschung GmbH

> 35 years experiences
Who is Minova-CT?

... the Minova-Group

▪ more than 1,300 heads in 60 countries
▪ 13 plants worldwide
▪ the **biggest supplier in chemicals for mining**

A member of the Orica Group
Who is Minova-CT?

A Solutions Provider

Understanding its customers
Premium on safety and efficiency
Products customised for local conditions
Qualified mining / civil engineers
Knowledgeable field operatives
Supplying associated accessories

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Chemical grouts were used for:
Sealing rock formations against water or gas
Waterproofing in construction pits
Cavity filling
Crack injection according to the ZTV Riss
Injection of self drilling bolts
Large area sealing against humidity in basements
Injection of grouting hoses in joints
...

More than one effect: Consolidation and Sealing or Bolting and Consolidation in one step.

Traditional roots:
German coal mine
But today we find these products in a lot of different fields.
Crack repairing

Reason for cracks:
- Building settlement
- Mistakes during the concreting
- Mistakes during the hardening
- Wrong calculation of the static
- Missing joints
- ...

We have do understand the reason for the damaging!

Minimal crack width:
- PUR: 0.3 mm
- AY: < 0.1 mm
- EP: 0.1 mm
- ZL: 0.8 mm (Zementleim)
Damaging situation

Final Tunnel shell with wet areas

Detail: Water is behind the concrete shell!
Damaging situation

Final Tunnel shell with cracks: Corrosion!
Damaging situation

Crack Injection with Acrylate
Linkou Tunnel

Injection Work

Railway tunnel / Taiwan

- Injection of injection hoses in block joints
- Injection of special plate construction, 24 for one tunnel block

- The project THSR C 210 is in total 6.5 km long.
The special design of the HDPE - membrane was done with:

- Tunnel consultant
- Membrane producer
- Grout producer
Similar System to Linkou Tunnel

- Reinforcement bars
- PVC water stop with fixing element for PREDIMAX
- Filling hoses for injection plate

PREDIMAX
- Injection hose

Detail Block joint with PVC water stop and HDPE membrane (grey)
Injection CarboCrack Seal NV and CarboStop F
Railway tunnel / Taiwan

- Injection of the injection hoses in the block joints
- CarboCrackSeal NV joint is only wet
- CarboStop F joint with pressure water
Injection hose

Construction joint in different steps – practice pictures

Construction

Application

Result
Injection hose

Detail for injection work with injection hose: Pressure + Time are important!
Injection Plates

Injection CarboCrack Seal NV
Railway tunnel / Taiwan

- Injection between tunnel lining and HDPE membrane
- Initial pressure + 3 bar
- Maximum 25 litre
  - Injection pump 1 comp. CT-ET I
  - Work in two shifts
Example of a flow chart for injection work: Plate injection to seal the existing HDPE membrane with one and two component PU resin.
Repairing different joint types

**Joints to find in constructions:**

**Construction joints:** assist in the construction and in the placement of concrete, e.g. wall - basement

**Expansion joints:** prevent concrete from crushing, displacing..., e.g. ramp - basement

**Contraction joints:** regulate the cracking controlling of concrete due to natural shrinkage, e.g. joints in a long concrete slab

**Further joints** like sliding joints, joggle joints, crack control joints (Dummy joints),...
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Repairing different joint types

Principal one injection hose in the joint

Principal two injection hose = each on one concrete segment
Typical damaged joint:
Water flows under pressure out of the joint, the PVC waterbar is without any function.
Repairing different joint types
Repairing different joint types

Site overview: Parking Garage in 2. Level
Repairing different joint types

Injection technic:
Acrylate pump with mixed components A and B
Repairing different joint types

Injection:

Packer with CarboCryl Hv Grouting up to a penetration at the surface or at the next packer.

Consumption: max. 20 l/lfm
Repairing different joint types

Problem

- Concrete and joints are porous due to the influence of the water
- Lock repairing need a stop of the water before the work can start
Repairing different joint types

Preparation injection work
Repairing different joint types

**Injection CarboPur WFA And CarboAdd Fast / Thix**
River lock / France

- Sealing of joints with ~2.0 bar water pressure and volume of 450 L/min.
- Injection pump CT-GX 45-II
### Overview and costs

#### Binghamian Fluids (Suspensions)
- Cement Mixes \(\text{PCM}\) Cement + Water
- Cement and Admixtures \(\text{ACM}\) PCM+Admixtures
- Cement and Additives \(\text{ADCM}\) ACM+Additives

#### Newtonian Fluids (Solutions)
- Epoxy Resins \(\text{EP}\) Resin + Hardener
- Methacrylic Resins \(\text{AC}\) Resin + Hardener + Catalyst
- Organomineral Resins \(\text{OM}\) Resin + Silicate Catalyst
- Polyurethane Resins \(\text{PU}\) Resin + Polyol Catalyst
- Phenolic Resins \(\text{PH}\) Resin + Catalyst
- Silicate Gels \(\text{SG}\) Silicates + Aluminates
<table>
<thead>
<tr>
<th>Diameter D&lt;sub&gt;15&lt;/sub&gt; (μm)</th>
<th>100.000</th>
<th>2.000</th>
<th>500</th>
<th>250</th>
<th>75</th>
<th>5</th>
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<tbody>
<tr>
<td>Crack Width w (mm)</td>
<td>10</td>
<td>5</td>
<td>1</td>
<td>0.5</td>
<td>0.1</td>
<td>0.05</td>
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<thead>
<tr>
<th>Realm of Soil</th>
<th>Gravel</th>
<th>Sand</th>
<th>Silt</th>
<th>Clay</th>
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<tr>
<td></td>
<td>ACM</td>
<td>ADCM</td>
<td>ADmCM</td>
<td>ADuCM</td>
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<tr>
<td>Binghamians</td>
<td>SG / OM</td>
<td>PU / PH / EP</td>
<td>ACM</td>
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<th>Permeability K (m/s)</th>
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<th>10&lt;sup&gt;-3&lt;/sup&gt;</th>
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Overview and costs
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<td>Polyurethane Resins (PU)</td>
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<td>Phenolic Resins (PH)</td>
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<td>Silicate Gels (SG)</td>
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**Flow shear resistance vs. cohesion vs. Shear velocity**

- **Binghamian Fluids**: Bingham and Newton regions.
- **Newtonian Fluids**: Grout Flow, "Bottle Neck".

- Maximum penetration: 3 times to 5 times $D_n$. 

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**Hong Kong**

Chien / Tatzki
Overview and costs

Crack repairing in concrete structures
Overview and costs

Latest technology for crack filling: CarboCrack Seal

1. Crack wet / dry: Injection of low viscose PU resin in one or two component method.

2. Crack water flowing: Injection of one comp. PU to stop the water. Finally injection see point 1.

Important to know is the reason for the crack.
Overview and costs

Our low viscous Polyurethane and the application:

CarboCrack Seal H
CarboCrack Seal NV
CarboCrack Seal T

Procedure Guideline:

For the repair of Polyurethane Fences
the filling of cracks
in many degree of hardening
in accordance with EN 1365-3

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Hong Kong
Overview about grouts

**Acrylates Gel**
Two Component Application, non foaming

Chain reaction = Polymerisation:
Resin is stimulated by a starter to form a chain.
Which grout is required?
1.) Depends from the injection target
2.) Depends from the access (e.g. packer, ...)
3.) Site parameter

Different targets:
- Filling
- Sealing
- Bonding
- Elastic connection (sealing)

Site parameter:
- Dry, wet or pressure water
- Cavities, size of the joint, gap
## Overview and costs

<table>
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<tr>
<th>Parameter</th>
<th>Target</th>
<th>Filling</th>
<th>Sealing</th>
<th>Bonding</th>
<th>Elastic connect.</th>
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<tbody>
<tr>
<td>Wet</td>
<td>PU, C, FC, (AY)</td>
<td>PU, C, FC, (AY)</td>
<td>C, FC</td>
<td>PU</td>
<td></td>
</tr>
<tr>
<td>Pressure water</td>
<td>PU, C, FC</td>
<td>PU, C, FC</td>
<td>C, FC</td>
<td>PU</td>
<td></td>
</tr>
</tbody>
</table>
Overview and costs

* These figures are not valid for each case and are based on common experience.
Overview and costs

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<th>Binghamian</th>
<th>Newtonian</th>
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<tbody>
<tr>
<td>Low Cost</td>
<td>Limited Penetration</td>
</tr>
<tr>
<td>Easy to Apply</td>
<td>Long Setting times</td>
</tr>
<tr>
<td>High E Modulus</td>
<td>Fragile Behaviour</td>
</tr>
<tr>
<td>High Penetration</td>
<td>Washable</td>
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<tr>
<td>Self Penetration</td>
<td>Low Jobsite Costs</td>
</tr>
<tr>
<td>Fast Setting</td>
<td>High Unit Price</td>
</tr>
<tr>
<td>Non Washable</td>
<td>Skilled Applicators</td>
</tr>
<tr>
<td>Low Jobsite Costs</td>
<td>Low E Modulus</td>
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</tbody>
</table>

Conclusion:
Whenever regular cement gout does not work, chemical grouts are a good alternative:

- **Salt or aggressive water**
- **Water pressure**
- **Difficult penetration**
- **Less space on the jobsite**
- **Flexible material required ...**
Overview and costs

- Post – grouting can be 10 to 50 times more expensive than pre – grouting.

- You do not have to seal if you can control the water:
  - TBM sites = \( \sim 0.5 \text{ m}^3/\text{min} \)
  - Drill and blast = \( \sim 2 – 2.5 \text{ m}^3/\text{min} \)
  - [Dry tunnel has 1 l – 30 l/min for 100m]

- Sealing of the first 80 – 90% costs easy the same like the remaining 10 – 20%.

- Grout quantity varies between 20 – 250 kg/m excavation

* These figures are not valid for each case and are based on common experience.
(1) Consultant and specialists for using grouts should **work together**

(2) Excavation in difficult areas with a pre- and post- **grouting schedule**

(3) Combination of suitable grouts – one type of grout cannot solve all problems!

(4) **Standby of material** for an urgent application, the extra costs are small in comparison to two days of excavation standstill

(5) Use only **qualified contractor** for injection work
(1) Drilling team and injection team belong together!

(2) Only trained people have to work with grouts. (own protection)

(3) Use quality possible environmental friendly grouts. - We have only one world!

(4) Injection system starts from the pump to the final packer or self drilling bolt. That must be a tested high pressure system. (Pump pressure easy > 50 bar)

(5) Record the injection work with pictures, technical drawings, flow and pressure measuring.
Thank you for your attention...

... and we are looking forward to welcome you in our world.

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