Innovative Backfill Grout for Dilative Soils
Germany

Presented by:
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Agenda

- Introduction
- Practical Example Backfill Grout for „Unteren Fildertunnel“
- Binder on Geopolymer Basis
- Performed Initial Assessment – Lab Trials
- Results of the First Tunnel Drive
- Conclusion
Introduction

- Mechanical tunnel drive in connection with segment lining shows increasing relevance worldwide

- So far backfill grout isn't included in the durability design of the construction object by default

- Nevertheless we recognize increasing consideration of backfill grout in the overall concept of securing long-term durability

- Increasing understanding that grout can be an intelligent material and not just a filler for embedding stones (e.g. drainage capable grout)
Practical Example Backfill Grout for “Unterer Fildertunnel“

Unterer Fildertunnel – special requirement meets innovation

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Practical Example Backfill Grout for „Unteren Fildertunnel“

Requirements Backfill Grout

- High volume stability
- No water release / preventing of swelling (anhydrate horizon)
- Durability 100 years
- High sulfate resistance
- Environmental sustainability
- Safety in practical application

Solution

- Usage of a binder on geopolymer basis
- Usage of a phosphate additive
Wagners Earth Friendly Concrete – Wellcamp Airport

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Mixture Optimization and Initial Tests

- Characterization of basic materials (ibac)
- Development of mix-design and optimization (site, MC, BUI)
- Mechanical properties (RUB)
- Water release, shrinkage, sources of surrounding anhydrate layer (ibac, BUI)
- Durablity (ibac, BUI)
- Effect of phosphate additive (ibac, MC, FIB, BUI)
- Environmental sustainability (ibac, BUI)
## Basic Materials and mortar composition

<table>
<thead>
<tr>
<th>Material</th>
<th>Type</th>
<th>Unit</th>
<th>Content</th>
</tr>
</thead>
<tbody>
<tr>
<td>Binder</td>
<td>Slag / Fly ash</td>
<td>kg/m³</td>
<td>~ 500</td>
</tr>
<tr>
<td>Activator 1</td>
<td>Sodium silicate</td>
<td>M.-% v. b.</td>
<td>10</td>
</tr>
<tr>
<td>Activator 2</td>
<td>Alkaline phosphate</td>
<td>M.-% v. b.</td>
<td>2,5</td>
</tr>
<tr>
<td>w/b</td>
<td>-</td>
<td>-</td>
<td>0,45</td>
</tr>
<tr>
<td>Plasticizer</td>
<td>Matched substance</td>
<td>M.-% v. b.</td>
<td>0,5</td>
</tr>
<tr>
<td>Aggregate</td>
<td>Quartzitic and calcitic sand/grit (7 mm)</td>
<td>kg/m³</td>
<td>~ 1.350</td>
</tr>
</tbody>
</table>

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Sulphate Resistance – Difference in Elongation

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Sulphate Resistance – Dynamic E-Module

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Water Release

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Effect of Phosphate Additive

- At presence of sodium or potassium phosphate the solubility of Sulphate declines significantly
- This can be proven by solubility products and the „law of mass“
- The anhydrite of the soil doesn't pass over into solution when getting in contact with the grout
- As a result, the anhydrite isn't swelling and

Source: F. A. Finger-Institut

Duration of storage

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Effect of Phosphate Additive

Why choosing phosphate solution?

- Solubilities:
  
  \[ L_{p_{\text{Gipsym}}} = [\text{Ca}^{2+}] [\text{SO}_4^{2-}] = 10^{-4.32} \]
  
  \[ L_{p_{\text{Phosphate}}} = [\text{Ca}^{2+}]^3 [\text{PO}_4^{3-}]^2 = 10^{-32.7} \]

- At presence of phosphate and sulfate the sulfate concentration goes down to 1/40000
Results of the first tunnel drive

- No stresses were measured
- Perfect workability until the backfill grout is activated – good pumpability even after several days
- Environmental friendly – confirmed by everyday external supervision
- Material consumption exactly as calculated
Conclusion

- The production of backfill grout using a binder on geopolymer basic is possible and working very well on site.
- The addition of an activator can happen at the pilaster strip – so you can react flexible when facing changing operating conditions.
- Grout stays workable above ground – significant cost reduction if TBM stands still (less cleaning costs).
- Usual mixing unit can be used.
- Also working as 2K-system without supporting grain for smaller diameters (e.g. metros).
- As expected, the grout shows a very high Sulphatic resistance by existing environmental sustainability.
- Water release is significantly lower compared to a classical 1K-grout.
- The usage of an phosphate additive prevents the conversion of anhydrite to gypsum – from our knowledge exclusive solution for such conditions.
Project Partner

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