hiDCon - high Deformable Concrete
an overview of projects
Patrick Steiner
- history and background
- hiDCon - Elements
- Yielding elements for shotcrete support
- Modular Yielding Support
- Compressible intermediate layer
- hiDCon-F
- NEW: hiDSte
history

- high overburden
- difficult rock, water and soil conditions
- squeezing ground expected
- ...

AlpTransit project

Lötschberg

Gotthard

Railway tunnel 1881
Highway tunnel 1980
Railway tunnel 2006
history

Situation
history

Mining experience  ➔  Adaption to tunnelling  ➔  Proof of concept 1:1 scale
The 1:1 scale tests showed that a system of TH profiles is working, but the load capacity of the system is significantly lower than expected.

Improving the load – deformation capacity of the lining system by using the shotcrete shell with in cooperated deformable elements.
background

Principle

- hiDCon - Elements
- Steel ribs with sliding connections
- Anchorage
- Sprayed concrete lining
Support resistance

- Support resistance $p_a$ vs. Radial displacement $u_a$
- Rigid and deformable models
- Graph showing $\Delta p_a$
Material properties

Yield stress
\( \sigma^*: 2 - 16 \, \text{N/mm}^2 \)

Strain \( \varepsilon \)

\( \varepsilon^*: 35 - 60 \% \)
Control of the element properties

Bearing capacity

Deformability

Cement (Type)
Cement (Ratio)
Water ratio
Aggregates
Concrete admixtures
Reinforcement

Air space ratio
Grading line
Steel fibre
Type of reinforcement
Geometry
Concrete admixtures
hiDCon - Elements

Properties

- High deformation capacity under nearly constant load resistance
- Increasing load resistance at the end of deformation capacity
- Variability of shape and dimension
- Control of bearing and deformation properties
- Application of approved base materials
- Insignificant creeping under constant longtime loading
hiDCon - Elements

Uniaxial compression test
hiDCon - Elements

Creep properties under longtime loading

Creep test: Constant Load
hiDCon - Elements

Creep properties under longtime loading
Yielding elements for shotcrete support

hiDCon – beam shaped element

Shotcrete strength Lötschberg

σ*: ca. 7 N/mm²

Stress [N/mm²]

Strain [%]

CFMR – AFTES - 2019
2004 the first tunnel support system was equipped with SOLEXPERTS’s high deformable concrete elements hiDCon. Beam elements are incorporated in the shotcrete lining for rock support and allowing tunnel convergence at the same time. Since then hiDCon elements have been further developed and a number of applications in squeezing and swelling ground could be realized. The major projects are:

- Lötschberg Base Tunnel (Switzerland); (squeezing rock)
- LTF Base Tunnel, Access Gallery St. Martin la Porte (France); (squeezing rock)
- Chienberg Road Tunnel (Switzerland); (swelling rock)
- Praclay experiment – HADES underground rock lab (Belgium); (compensation of thermal expansion)
- Bure, ANDRA underground rock lab (France) (long term squeezing induced by swelling)
- Cigar Lake Mine (Canada); (squeezing induced by ground freezing)
Yielding elements for shotcrete support

Application: Lötschberg base tunnel
Yielding elements for shotcrete support
Application: Lötschberg base tunnel
Yielding elements for shotcrete support
Application: Access tunnel St. Martin la Porte (LTF)
Yielding elements for shotcrete support

Application: Access tunnel St. Martin la Porte (LTF)
Yielding elements for shotcrete support

Application: Access tunnel St. Martin la Porte (LTF)
Yielding elements for shotcrete support

Application: TELT
Yielding elements for shotcrete support

Application: Cigar Lake Mine
Yielding elements for shotcrete support

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Yielding elements for shotcrete support

Application: Cigar Lake Mine
Yielding elements for shotcrete support

Application: Cigar Lake Mine

Source: Internet
Modular Yielding Support

Chienberg road tunnel

Total length: 2.3 km

Mining operation: 1.5 km
Modular Yielding Support

Cross section – resistance principle

R = 5.95 m
Modular Yielding Support

resistance principle vs. reality
Modular Yielding Support

Bottom heave

1.20 m
Modular Yielding Support

Heave zone 1

Heave [mm]

max. 83 mm

max. 30 mm

Time

2002

2003

Tunnel

Surface
Modular Yielding Support

Alternatives

Knautschzone
Yielding zone

Felsanker
Rock anchor

5m
Modular Yielding Support

Reconstruction

- Existing lining
- New construction
- Initial Lining
- hiDCon-Elements
- Rock anchors
Modular Yielding Support

1:1 Pre-Tests

Deformation: 0 %

Deformation: 25 %

Deformation: 50 %

Deformation: 50 %
Modular Yielding Support

Foundation element

<table>
<thead>
<tr>
<th>Type</th>
<th>Yield stress $\sigma^*$ [N/mm$^2$]</th>
<th>Yield stress $\sigma_{\text{max}}$ [N/mm$^2$]</th>
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</tbody>
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Modular Yielding Support

Anchor element
Modular Yielding Support

Anchor elements
Modular Yielding Support

Anchor element ( stamping principle )

Ankerstab
Rod

Lastplatte
Plate

Knautschkörper
Yielding body
Modular Yielding Support

Anchor element (stamping principle)

max. anchor load: 1650 kN
Modular Yielding Support

Reconstruction
Modular Yielding Support Reconstruction
Modular Yielding Support

Heave measurements

Heave of the crown [mm]

Installation yielding elements heave zone 2

Installation yielding elements heave zone 1

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The development of Compressible Intermediate Layers for TBM:

Requirements:

• Enabling TBM applications in tunnels and shafts with high ground pressure development on the lining

• Compatibility with handling and erection of commonly used prefabricated concrete segments

• Integration of the compressive intermediate layer into the concrete segments

• Cost saving in squeezing ground
Compressible Intermediate Layer

TBM application in squeezing and swelling rock

hiDCon-F element

concrete segment
Compressible Intermediate Layer

TBM application in squeezing and swelling rock
Compressible Intermediate Layer

TBM application in squeezing and swelling rock

Concrete segments

hiDCon-F

Gap backfilling
Compressible Intermediate Layer

Application for shaft sinking

shaft lining

hiDCon-F
hiDCon-F is an advancement of the proven cement based hiDCon mixture.

Due to an innovative combination of new additives and novel reinforcement components the typical, plateau style stress-deformation behaviour of the hiDCon element was achieved on considerable lower yield stress levels.

Fully constrained lateral strain load tests of hiDCon-F elements reveal stress – deformation curves which are most favourable for area – measured applications.
Typical hiDCon-F stress – deformation curves
NEW's

Development of hiDSte
high Deformable Steel element

Potential solution to cross heavily squeezing rock zones
(example: TELT, charbon houillère)
Target of development:

- An element to enable deformation for sections with a higher load capacity as TH-sections or lattice girders.
- Element with moment bearing and shear force capacity.
hiDSte

Development of hiDSte

Idea
Technical drawing
Numerical calculation
Validation of numerical calculation
Development of hiDSte
Development of hiDSte

Test vs. FEM; tube 120.6 x 12.5 l=120mm

Load [kN]

Total deformation [mm]

- Test tube with prism
- 2D FEM model with prism
- 2D FEM model with rounded prism

numerically unstable
Thank you for your attention