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DEVELOPMENT AND APPLICATION OF STRESS CONTROLLERS – SYSTEM HONEYCOMB – IN MODERN TUNNELLING

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DEVELOPMENT AND APPLICATION OF STRESS CONTROLLERS – SYSTEM HONEYCOMB – IN MODERN TUNNELLING

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Abstract

After a short retrospect on possible elasticity the intended purpose of stress controllers as rock support elements in shotcrete construction is described. Different types of stress controllers are briefly explained. The successful development as well as the technical versions of the stress controller type - HONEYCOMB - is explained in detail. Experiences in first use at Tauerntunnel with its system components are presented. Further possible fields of application and developments are elaborated.

1. RETROSPECTION OF POSSIBLE YIELDINGNESS

Timber supports, for example timber cribs, have ever been known as yielding elements *(picture 1)*.

Picture 1: timber cribs

In the 20^{s} of last century the conclusion was reached to protect steel support against overstraining by hinges or designed yield ability as well as to prevent sudden failure. *(picture 2)*.

Picture 2: Moll support

Milestones in further developments were articulated Moll support in 1924 and TH support of Bochumer Eisenhütte Heintzmann (*picture 3)*, first used 1933 in Germany.

Picture 3: timber cribs and yieldable steel support

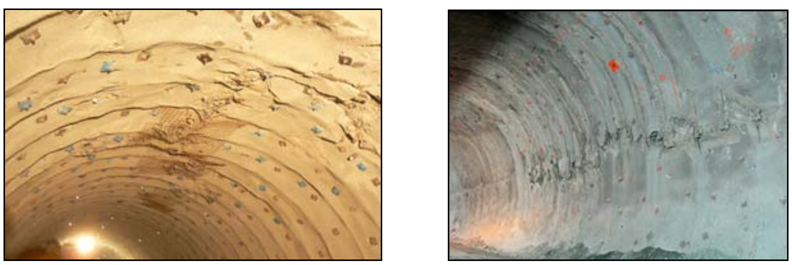
State of technology of yieldable TH section in use is shown at Gotthard Basetunnel, Sedrun sector *(picture 4)*.

Picture 4: Yieldable TH-support

2. INTENDED PURPOSE OF STRESS CONTROLLERS

New options of yield ability in pressurised rock arose from use of shotcrete method.

One essential design element of conventional tunnelling is to use the strata as part of support. Stress relief at cavity leads to relocation of rock stress – the rock support ring is shaped. Depending on rock properties and level of primary stress substantial deformations may occur, sometimes over continuing months *(picture 5)*.



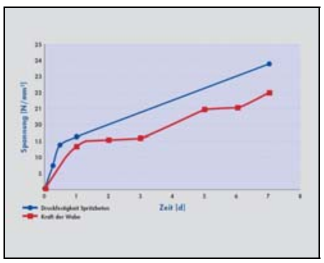
Picture 5: demolitions of shotcrete

Support with shotcrete cannot take higher deformation of strata without damages. At higher deformation level spalling and in consequence demolition of shotcrete shell happens.

Stress controllers *(picture 6)* act as strata support elements dividing circular shotcrete support into segments and are able to absorb most of the deformations.

Picture 6: Support with stress controller, System Honeycomb

Ideally, the characteristic diagram of stress controllers *(picture 7)* is just below that of virgin shotcrete. Due to not precisely projectable deformation speed it is difficult to forecast an optimal characteristic diagram.



Picture 7: characteristic diagram of stress controller, System Honeycomb

3. DIFFERENT TYPES OF STRESS CONTROLLERS

Deformation slots *(picture 8)***:**

Primary, deformation slots were left open in shotcrete shell allowing motions and were closed by spraying after finishing of deformation. Good experiences were made for example at Inntaltunnel by combination of this system with strong rockbolting. By open slots frequent overexcavation of strata and spalling of shotcrete occurred.

Picture 8: deformation slots

Stress controllers

For safety reasons and early use of shotcrete shell as support element stress controllers made of steel or deformable substance (for example foam mortar) are used. Today three different systems are used:

- **Foam mortar blocks or special concrete composition** *(picture 9)*

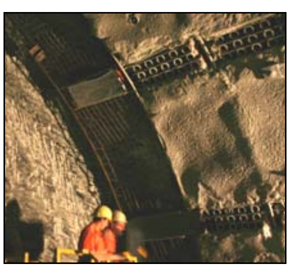
Picture 9: foam mortar blocks or special concrete composition

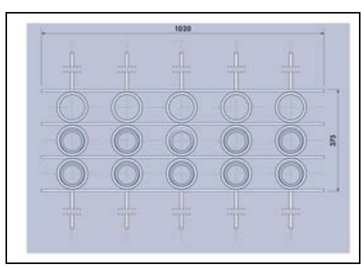
- **LSC-Elements made of deformable tube structure** *(picture 10)*

Picture 10: LSC-Elements made of deformable tube structure

Adaption to real deformation behaviour at site of foam mortar blocks and LSC-elements is difficult.

- **System Honeycomb** *(picture 11)*





Picture 11: System Honeycomb

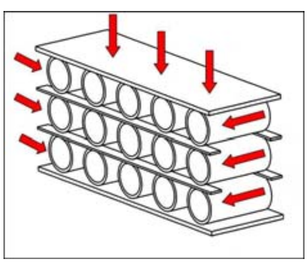
Stress controller called Honeycomb of Bochumer Eisenhütte Heintzmann is located between load distributing plates. It consists of flat lying tube sections in needs-based wall thickness and diameter.

4. THE SUCCESSFUL DEVELOPMENT OF HONEYCOMB SYSTEM

Stress controller honeycomb is mainly set between two arched supports made of yieldable TH sections or deformable lattice girders. It for example consists of circular hollow sections divided or rather linked by intermediate plates *(picture 12)*. The upper or rather lower sheet includes fixing elements for mounting and assembling at the support and armouring elements for armoured concrete compound.

Picture 12: Honeycomb set between 2 lattice girders

The system HONEYCOMB allows force acceptance in tangential (normal force) as well as in radial direction (transverse force), moreover in axial direction (longitudinal force in direction of development) *(picture 13)*. The chosen load-displacement diagram depends on choice of utilized tubes, which means it is controllable by tube rating (tube diameter, tube wall thickness, length of tube pieces plus choice of material and steel quality). By selection of different tube combinations optional load-displacement graphs can be generated (from flat rising to steep increasing).



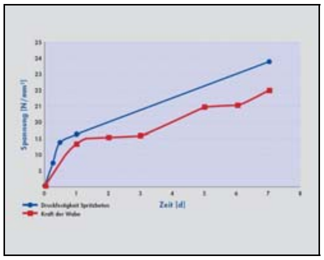
Picture 13: force acceptance of Honeycomb

The design of stress controller HONEYCOMB permits adaption of load bearing capacity to individual strata conditions during strata deformation. This is done by pulling additional tube pieces into existing tubes.

Temporary hardening of shotcrete is supported by deformability of stress controller HONEYCOMB (deformation of tube sections) and avoids as far as possible cracks in shotcrete shell.

By the great variety of possible combinations as to number of tube layers, diameters and wall thickness of several tubes as well as its number per layer, a maximum of flexibility and adaptability of HONEYCOMB to strata behaviour is achieved.

At stress controller HONEYCOMB normal force *(picture 14)* raises continuously in shotcrete shell, which means even. Working graph of HONEYCOMB has a steeples gradient. At HONEYCOMB the horizontal position of tubes and its welding joint with load transforming sheets supplies increased transverse rigidity and thus better transverse force transformation at deformation slots in shotcrete shell.



Picture 14: compressive strength

By appropriate choice of tubes and combination in number of layers a more or less variably higher deformation path can be achieved.

Advantages:

- Definable, additional yielding resistivity by use of variable designed tubes.
- Adjustment of pre-defined resistances (constant or increasing).
- Definable yieldingness path.
- Use of different types and materials of layer elements possible.
- Good handling by modular principle.
- Endless compound element due to additional injection of foam mortar
- Adjustable design

5. EXPERIENCES AT TAUERNTUNNEL

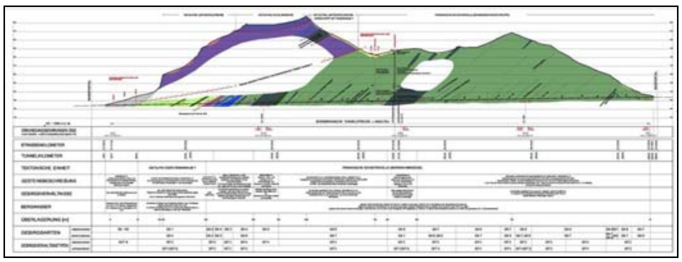
Picture 15: Tauerntunnel

The Tauerntunnel is part of the Tauernhighway from Salzburg to Villach. The first tube of the approximately 6.4km long tunnel began 1971 and was finished in 1975.

The second tube is under construction since July 2006 – more than 30 years after finalization of the first tube.

The first blasting took place at 15th September 2006. The pilot cut was carried out on 8th July 2008 after 22 months of tunnel driving. Opening of the second tube for traffic is planned for June/July 2010.

Tauerntunnel traverses mainly phyllite rocks *(picture 16)* except an approximately 400m long talus drift in the north. Cleavage planes dip from north to northwest.



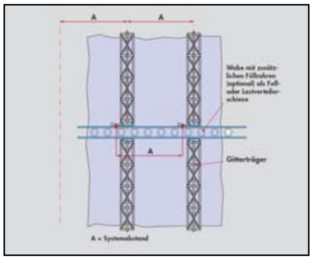
Picture 16: geological forecast Tauerntunnel

From experiences during driving of the first tube the squeezing rock conditions at Tauerntunnel were known. During planning stress controllers were envisaged to absorb the expected and longer enduring deformations free of damage.

At situ in Tauerntunnel *(picture 17)* the mainly used system HONEYCOMB proves itself in practice. Due to contractual provisions (parity to tendered LSC system) the spatially dimensions as well as the load capacity had to be adapted. The adaption of stiffness by insertion of additional tubes was easily handled and very effective.

Picture 17: First use of Honeycomb in Tauerntunnel

6. FUTURE APPLICATION AND DEVELOPMENT SCOPES



Picture 18: Honeycomb used as yieldable load transformation beam

By development of the flexible element HONEYCOMB further application fields are conceivable. The system could for example be used as yieldable load transformation beam. Particularly in slightly pressurised rock the system can effect an improvement of connection to bench or rather to invert in case the ring closure needs to be build fast for static reasons and long lasting deformations at contemporaneous high stress level.

Picture 19: Successful use Tauerntunnel

REFERENCES:

(1) Gaulhofer, Schwaiger, Podjadtke: Stress Controller with Resistance Reinforcement. Tunnel 08/2008 S. 40-43.

(2) Bochumer Eisenhütte Heintzmann GmbH & Co. KG: The Wabe ductile Honeycomb – a yielding element for the preservation on the shotcrete shell under high rock stresses. Geomechanics and Tunnelling 2 (2009), No. 1, page 117-118.

PHOTOGRAPHS: