THE AUSTRIAN ART OF TUNNELLING

in Construction, Consulting
and Research

Issued by the Austrian National Committee of ITA – ITA-Austria
## Contents

### I. Associations

<table>
<thead>
<tr>
<th>Author</th>
<th>Title</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wolfgang Stipek</td>
<td>Introduction</td>
<td>9</td>
</tr>
<tr>
<td>Robert Galler</td>
<td>Austria’s Activities in Tunneling in 2007/2008</td>
<td>11</td>
</tr>
<tr>
<td>Robert Galler &amp; Wulf Schubert</td>
<td>The Austrian Society for Geomechanics (ÖGG)</td>
<td>13</td>
</tr>
<tr>
<td>Rudolf Hörhan</td>
<td>Guideline-oriented Activities of the FSV Tunnel Work Group</td>
<td>14</td>
</tr>
<tr>
<td>Michael Pauser</td>
<td>Austrian Society for Concrete and Construction Technology (ÖVBB)</td>
<td>16</td>
</tr>
<tr>
<td>Wolfgang Stipek</td>
<td>Austrian Tunnel Association ‘ATA’</td>
<td>16</td>
</tr>
<tr>
<td>Harald Wagner</td>
<td>Activities of the Austrian Society of Engineers and Architects (ÖAIU)</td>
<td>17</td>
</tr>
<tr>
<td>Wolfgang Stipek</td>
<td>Austrian Construction Technology Platform (ACTP)</td>
<td>18</td>
</tr>
<tr>
<td>Wolfgang Stipek</td>
<td>D-A-CH Meetings</td>
<td>18</td>
</tr>
</tbody>
</table>

### II. Recommendations

<table>
<thead>
<tr>
<th>Author</th>
<th>Title</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Michael Pauser</td>
<td>Austrian Guidelines for “Customised Concrete” in Tunnels</td>
<td>20</td>
</tr>
<tr>
<td>Manfred Eder</td>
<td>Recommendations for the Planning and Implementation of a Health and Safety Concept in Underground Worksites</td>
<td>23</td>
</tr>
</tbody>
</table>

### III. Universities

<table>
<thead>
<tr>
<th>Author</th>
<th>Title</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Robert Galler</td>
<td>Chair of Subsurface Engineering</td>
<td>26</td>
</tr>
<tr>
<td>Hans Georg Jodl</td>
<td>Main Activities Related to Tunneling at Vienna University of Technology</td>
<td>28</td>
</tr>
<tr>
<td>Eckart Schneider</td>
<td>Main Activities Related to Tunneling at University of Innsbruck</td>
<td>30</td>
</tr>
<tr>
<td>Wulf Schubert</td>
<td>Graz University of Technology – Institute for Rock Mechanics and Tunneling</td>
<td>33</td>
</tr>
<tr>
<td>Robert Galler &amp; Wulf Schubert</td>
<td>University Certificate Programme – NATM Engineer</td>
<td>35</td>
</tr>
<tr>
<td>Gernot Beer</td>
<td>European Project: Technology Innovation in Underground Construction</td>
<td>36</td>
</tr>
</tbody>
</table>

### IV. Tunnelling in Austria – Railway Tunnels

<table>
<thead>
<tr>
<th>Author</th>
<th>Title</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Franz Bauer</td>
<td>ÖBB’s Investments in Infrastructure and Tunnel Construction</td>
<td>38</td>
</tr>
<tr>
<td>Karl Cropak</td>
<td>Lainzer Tunnel – Lot LT 33</td>
<td>41</td>
</tr>
<tr>
<td>Manfred Öfferl</td>
<td>Lainzer Tunnel – Lot LT 44</td>
<td>44</td>
</tr>
<tr>
<td>Martin Diewald</td>
<td>Wienerwald Tunnel – Austria’s First TBM-driven Railway Tunnel</td>
<td>47</td>
</tr>
<tr>
<td>Manfred Köpf</td>
<td>The Perschling Chain of Tunnels</td>
<td>50</td>
</tr>
<tr>
<td>Gerhard Haringer</td>
<td>Koralm Railway Tunnel</td>
<td>54</td>
</tr>
<tr>
<td>Markus Bitschnau</td>
<td>P amendments Investigation Shaft – Planning of Excavation Methods</td>
<td>57</td>
</tr>
<tr>
<td>Hannes Hagenhofer</td>
<td>Investigation Tunnel Mitterpichling</td>
<td>60</td>
</tr>
<tr>
<td>Johann Herdina</td>
<td>Tunnel Projects on the New Lower Inn Valley Railway Line</td>
<td>62</td>
</tr>
<tr>
<td>Karl Cropak</td>
<td>Brixlegg Tunnel – Lot H2-1</td>
<td>64</td>
</tr>
<tr>
<td>Bernd Raderbauer</td>
<td>The Lower Inn Valley Railway Line – Main Lot H3-4 between Münster and Wiesing</td>
<td>67</td>
</tr>
<tr>
<td>Christian Gamper</td>
<td>Jenbach Tunnel Project</td>
<td>70</td>
</tr>
<tr>
<td>Konrad Bergmeister</td>
<td>The Brenner Base Tunnel</td>
<td>72</td>
</tr>
</tbody>
</table>

### V. Tunnelling in Austria – Road Tunnels

<table>
<thead>
<tr>
<th>Author</th>
<th>Title</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Michael Steiner</td>
<td>The Importance of Tunnel Construction for Austria’s Major Road Network</td>
<td>75</td>
</tr>
<tr>
<td>Wolfgang Pacher</td>
<td>PPP Eastern Region – Tradenberg Tunnel</td>
<td>78</td>
</tr>
<tr>
<td>Hans Gaulhofer</td>
<td>A10 – Tauern Tunnel Second Tube</td>
<td>82</td>
</tr>
<tr>
<td>Gerhard Brugger</td>
<td>Ropen Tunnel Second Tube</td>
<td>84</td>
</tr>
<tr>
<td>Franz Weidinger</td>
<td>Ganzstein Tunnel</td>
<td>87</td>
</tr>
<tr>
<td>Helmut Westermayer</td>
<td>The Achrain Tunnel – A Bridge Going Underground</td>
<td>90</td>
</tr>
<tr>
<td>Norbert Reichard</td>
<td>Expansion of the Brucker Schnellstraße S35</td>
<td>94</td>
</tr>
<tr>
<td>Hans Gaulhofer</td>
<td>Gfäll Tunnel – A Logistics Challenge</td>
<td>98</td>
</tr>
</tbody>
</table>

*The Austrian Art of Tunneling*
Contents

VI. Tunnelling in Austria – Subway Tunnels
Günter Steinbauer
Vienna Underground – The Extension of the Subway Line 2 ........................................ 100
Christof Haberland
Vienna Underground Lot U2/1 – Schottenering .......................................................... 102
Georg Punztigam
Vienna Underground Lot U2/2 – Traborstraße ............................................................. 105
Hans Köhler
Vienna Underground Lot U2/5 – Stadion ........................................................................ 108

VII. Tunnelling in Austria – Hydro Power Projects
Helmut Westermeier & Michael Treipl
Construction of the Powerhouse Cavern Kops II ......................................................... 110
Rupert Rohrmoser
Limberg II Pumped Storage Power Station ................................................................. 114

VIII. Tunnelling in Austria – Utility Tunnels
Norbert Hörlein
North West District-Heating Line – Phase 2 ................................................................. 119
Arthur Göbl
Wiental Collector ........................................................................................................... 121

IX. Activities of Austrian Construction Companies Abroad
Germany
Günter Rudigier
Construction of the Katzenberg Tunnel by Two Tunnel Boring Machines ........................ 124
Christian Späth
Leipzig City Tunnel, Section B: A Complex Inner-City Project .................................... 127
Friedrich Neureiter
Upgrading The “Alte Mainzer” Tunnel ............................................................................ 130
Klaus Arthausen
German Unity Transport Projects – Finne Tunnel ........................................................ 132
Andreas Karlbauer
The Schaala By-Pass ...................................................................................................... 134

Switzerland
Thomas Aschwanden
Gotthard Base Tunnel – Lots Erstfeld and Amsteg ....................................................... 136
Arthur Göbl
Biel Motorway By-Pass – East Branch ........................................................................... 140
Alfred Paul
Chienberg Tunnel – Remedial Measures Against Heave .............................................. 142
Reinhard Bukowsky, Wolfgang Poschacher & Robert Wachtler
Uetliberg Water Transfer Tunnel – High Performance TBM Heading from Launching Shaft ................................................................. 144

Great Britain
Christian Neumann
King’s Cross Underground Station Phase II Tunnels ..................................................... 148

Sweden
Norbert Füngenschuh
Tröingeberg Railway Tunnel in Falkenberg, Sweden ................................................... 151

Croatia
Robert Pavlik
The Development of the Croatia Road Network 2002 to 2008 .................................... 154
Christof Haberland
Sopac Tunnel in Croatia ................................................................................................ 156

Hungary
Dietmar Kerbis & Andreas Krimmer
The Tunnels on the New Motorway M6 in the Szekszárd-Boly Secton in Hungary .... 158
Julius Hirsch
Metro 4 Line Budapest – Contract No. 2 ..................................................................... 162

Canada
Ernst Gschnitzer & Pedro Rojas
Niagara Tunnel Facility Project – NTIP ....................................................................... 164

India
Wolfgang Güttler
Parbati HEP Project Stage II ....................................................................................... 166
Gerhard Brugger
Modaksagar Tunnel – Potable Water for a Cosmopolitan City .................................. 168

China
Melk Müller
Yellow River Diversion Project – Lot IV of Tunnel No. 1 on the North Main Line .... 171

X. Consulting Engineers
Josef Dailer
Design of Wienerwald Railway Tunnel Project ......................................................... 174
Andreas Goricki
Difficult Tunnel Projects – Egnatia Odos, Northern Greece ......................................... 176
Harald Wagner
River Crossing Tunnel in China – Mixed Soils for TBM Tunnelling .......................... 178
Nejad Ayaydin
Metro Kadiköy – Karteal, Istanbul ................................................................................ 180
Manfred Eder
Linz Commuter Traffic Hub – Tram Underpass for Central Station ......................... 182
Rudolf Pöttler & Paul Bonapace
Sir Adam Beck Niagara Power Generating Complex ................................................ 184
Wolfgang Holzmeister
The Dagachhu Hydropower Project, Bhutan ................................................................ 187
Gernot Jedlitschka & Bernhard Stacherl
CERN LHC Project – Civil Works Package 02 ............................................................. 190

Appendix
List of Authors .................................................................................................................. 192
List of Associations and Universities ............................................................................. 196
List of Companies ............................................................................................................ 197
Advertisers’ Index .......................................................................................................... 199

The Austrian Art of Tunnelling
Main Activities Related to Tunnelling at Vienna University of Technology

Tunnelling as a comprehensive topic is given attention in several courses at four institutes in the Faculty of Civil Engineering at Vienna University of Technology. The study of Civil Engineering is divided into the basic bachelor course and three bottom-up master courses.

At the Institute for Mechanics of Materials and Structures (IMVS) under the leadership of o.Univ.-Prof. Dipl.-Ing. Dr. techn. Dr. h.c.mult. Herbert Mang, PhD., tunnel engineering is being advanced by assessing the safety of NATM tunnel shells (i) during construction and (ii) under fire load. For this purpose, underlying physical mechanisms in shotcrete and concrete are quantified using multi-scale constitutive models, which are in turn used for Finite Element (FE) simulations of tunnel shells.

For the safety assessment of tunnel shells during construction, three-dimensional structural models of shotcrete tunnel shells are fed, in terms of boundary values, by displacement vectors measured in-situ at discrete points of the tunnel shell [1]. The underlying mixture-dependent shotcrete material behavior is predicted from multi-scale continuum micromechanics formulations [2], [4], (Figure 1). Such hybrid analyses provide the evolution of the level of loading (i.e. the ratio of stress over strength) throughout the tunnel shell, allowing for its online monitoring.

When concrete is subjected to high-temperature loading, thermo-hydro-chemo-mechanical processes cause degradation of stiffness and strength of the linings materials, i.e. concrete and steel, and spalling of near-surface concrete layers [3], [6]. As a consequence, the load-carrying capacity of the tunnel structure is reduced. Related research work at the IMVS is based on large-scale fire experiments, (Figure 2), highlighting the concrete mix-dependent extent of spalling [3], significantly reduced by PP fibre reinforcement [6]. Permeability tests, mercury intrusion porosimetry, thermogravimetric and nanoindentation tests provide the experimental basis for structural safety assessment of tunnels under fire load by coupled thermo-hydro-chemical FE simulations [5].

Failure Mechanisms of tunnels as well as of slopes and foundations are a special field of research of the Institute for Engineering Geology under the leadership of o.Univ.-Prof. Dr. phil. Ewald Tentschert. During the last years, the "cherry pit mechanism" ("notching"; squeezing out of the side walls due to predominant vertical in-situ stresses) has been investigated, using continuum as well as discontinuum mechanics methods. Figure 3 shows a numerical model of this mechanism using the particle flow code PFC. The formation of notches in the sidewalls as well as the deformations in the roof and in the invert, being considerably smaller than those of the sidewalls, are simulated very well. The advantage of the discontinuum mechanics programme PFC is that large displacements of each particle and thus of the whole structure can be simulated, considering contacts of every particle with every other particle. These models make optimizations of the excavation sequence, of the support as well as of the monitoring system possible.

The tunnelling education on offer is included in various courses of engineering geology and deepened in the special courses "Underground Excavation Design" and "Finite-Difference-Modell in Geoengineering".

Research activities at the Institute for Soil Mechanics and Geotechnical Engineering under the leadership of o.Univ.-Prof. Dipl.-Ing. Dr.techn. Dr.h.c.mult. Heinz Brandl. Tunnelling research focuses on two main topics: First is "Residual shear behaviour and progressive failure of soil or weak rock in tunnelling". The operational shear strength of soil and decomposed weathered rock depends on several factors and is not a constant parameter. Therefore, tunnel design, construction method and risk analysis should take into account the post-failure behaviour and residual strength, also comprising the tendency to progressive failure in the surrounding ground.

The second topic is "Geothermal use of tunnels". Tunnels can be used for geothermal heat extraction and storage, thus contributing to sustainable energy utilisation. Research investigates cut-and-cover tunnels as well as open and closed face tunnels (NATM; tunnel linings) i.e. "thermo active traffic tunnels" ("energy tunnels"). Conventional geothermal energy can be used for heating buildings near the tunnel. Thermo-active tunnel linings, however,
enable heat extraction from the ground via absorber pipes that carry a heat carrier fluid. Seasonal operation makes cooling during summer possible by using the ground for heat storage. Meanwhile all metro stations of the new Vienna Metro extension U2 are supplied with geothermal energy from earth-contact structures for both heating and cooling purposes. This is the first application of “energy metro stations” worldwide. Finally, wells for groundwater lowering along near-surface tunnels can be also used for geothermal heat extraction/storage. These “energy wells” have proved successful in Vienna for temporary and permanent purposes. The benefits of thermo-active earth contact structures are being investigated further; they are certainly a great potential (and need) for innovative, environmentally friendly systems.

The tunneling education on offer is included in the courses for “Ground Engineering and Soil Mechanics” and “Rock Engineering”.

The Institute of Interdisciplinary Construction Process Management under the leadership of Dr.-Ing. Hans Georg Jodl consists of three chairs for construction technology (Jodl), construction economy (Hromek), and construction planning (Aichhammer). The main research activities in tunneling are focusing on contractual problems, site organisation and economical as well as technical optimisation. The evaluation, assessment and management of the tunnel construction process have become a major topic of tunnel engineering research within the chair of construction technology as a powerful partner of industry. Draughting of expert reports for the guidelines “Segmental Lining” and “Tunnelling Shield Machines” as well as “Concrete Use in Tunnels” are current intensive contributions.

The chair of construction technology offers basic tunnelling topics in the bachelor lecture “Construction Technology”. In the continuing master course “Construction Industry and Geotechnics”, tunnelling education is deepened in the lectures “Tunnel Construction Technology” including tutorial and the lecture “Design of Infrastructure Tunnels”. Research students often produce their special diploma thesis on tunnelling topics with the overall goal of promoting the increased use of underground space for infrastructure facilities, which will be carried out in close cooperation with the Austrian tunnelling industry.

Hans Georg Jodl

References

Austrian tunnel engineering is highly developed and has an excellent reputation worldwide in all areas including design, execution, innovative developments and training. The Austrian Art of Tunnelling aims to document the current state of the art. Short articles present current construction sites in Austria and abroad, their special features and the chosen solutions. In addition, internationally experienced consulting engineers discuss the design challenges for selected, particularly demanding projects. The book is rounded off by a clearly arranged overview of relevant technical/scientific organisations, associations and universities.

The Austrian Art of Tunnelling is published by ITA Austria, Vienna, an umbrella organisation formed by five technical/scientific associations – Austrian Society for Geomechanics (ÖGG), Austrian Tunnel Association (ATA), Austrian Society of Concrete and Construction Technology (ÖVBB), Austrian Association for Research on Road, Rail and Transport (FSV), Austrian Society for Engineers and Architects (ÖIAV) – that represents Austrian interests in the International Tunnelling Association.