DESIGN AND CONSTRUCTION OF LARGE TUNNELS IN SOIL AND FAULTED ROCK

LAINZER TUNNEL PROJECT

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LAINZER TUNNEL PROJECT
LAINZER TUNNEL PROJECT

- Total Length: 12.8 km
- Mined tunnels in Flysch: 14
- Mined tunnels in soil: 14
- Cut & Cover tunnels: 13

Locations:
- Penzing
- Fünfhaus
- Transition Lainzer- to Wienerwaldtunnel
- Hietzing
- Meidling
- LT 44

Map showing the locations and types of tunnels.
LAINZER TUNNEL PROJECT – CONSTRUCTION LOT LT44

excavation of single-track tunnels

excavation of double-track tunnel

double-track tunnel

cut&cover tunnel

double-track tunnels

single-track tunnels
CONSTRUCTION LOT LT44 - OVERVIEW

- 2 starting shafts
- 957,4 m single-track tubes with about 84 m² excavation cross section
- 128,5 m double-track tube with about 129 m² excavation cross section
- 110,9 m widening of double track tube to maximum 182 m² in 3 steps
- 89 m special section with concrete pillar at transition to single track tubes
- 2 Emergency exit shafts and emergency galleries
- Conventional tunneling by using NATM
- Overburden between 7,5 m and 15,5 m
CONSTRUCTION LOT LT44 – GEOLOGY/HYDROGEOLOGY

■ Tertiary soil of Miozäns (Pannon)
■ Consisting mainly of silt/clayey silt with intercalations of sand and gravel, gently dipping
■ In some areas sand and gravel layers are well cemented
■ Mainly two groundwater aquifers, separated by layers of silt/clayey silt
■ Lowering of groundwater table ahead of tunneling, mainly by vertical wells
CONSTRUCTION LOT LT44 – GEOLOGY/HYDROGEOLOGY

TYPICAL GEOLOGICAL PROFILE

LEGENDE

- FILL
- SAND
- GRAVEL
- SILT

GAS „Sand“
GAS „Schluftor“
GAS „Kasch“
GAS „Schluftor“
GRUNDWASSERNIVEAU “KES” vom 8.6.2006
GRUNDWASSERNIVEAU “SAND” vom 8.6.2006
GRUNDWASSERSTAND am 2.2.2006 bzw. Dateiangebot

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## CONSTRUCTION LOT LT44 – SOIL PARAMETER FOR FE-ANALYSES

<table>
<thead>
<tr>
<th>Type of Soil</th>
<th>Friction Angle</th>
<th>Cohesion</th>
<th>Unit weight/Unit weight under bouyancy</th>
<th>void ratio</th>
<th>Young`s Modulus first loading</th>
<th>Young`s Modulus unloading/reloading</th>
<th>Poisson Ratio</th>
<th>Permeability</th>
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<tbody>
<tr>
<td>Fill material</td>
<td>25</td>
<td>5</td>
<td>20/10</td>
<td>0,65</td>
<td>15</td>
<td>30</td>
<td>0,37</td>
<td>-</td>
</tr>
<tr>
<td>Gravel</td>
<td>35</td>
<td>5</td>
<td>22/12</td>
<td>0,38</td>
<td>130</td>
<td>200</td>
<td>0,30</td>
<td>1x10⁻³</td>
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<tr>
<td>Silty Sand</td>
<td>30</td>
<td>10</td>
<td>21,5/11,5</td>
<td>0,43</td>
<td>80</td>
<td>120</td>
<td>0,33</td>
<td>5x10⁻⁵</td>
</tr>
<tr>
<td>Clayey Silt/Silt</td>
<td>20</td>
<td>40</td>
<td>20,5/10,5</td>
<td>0,67</td>
<td>35</td>
<td>60</td>
<td>0,40</td>
<td>1x10⁻⁸</td>
</tr>
</tbody>
</table>
CONSTRUCTION LOT LT44 – SINGLE-TRACK TUBES

CROSS SECTION

- Single-track tube
- Shotcrete lining (min. 30 cm)
- Watertight inner lining (d=50cm)
- Excavation area 84 m²
CONSTRUCTION LOT LT44 – SINGLE-TRACK TUBES

EXCAVATION AND SUPPORT

• Excavation subdivided in top heading, bench and invert
• Excavation in several steps in top heading and bench
• Round length: Top heading 1.0 m
  Bench 1.0 m
  Invert arch 2.0 m
• Short ring closure distance (max. 8 m behind top heading face)
• Min. 30 cm reinforced shotcrete (2 layers of wire mesh)
• Application of lattice girder and forepoling (length 3 – 4 m)
• Face support: Reinforced shotcrete (5-10 cm)
  12 m face bolts (overlap 6 m)
  Support core
• Underground: Silt/silty Sand/Sand
• Max. settlements: Surface 10 mm
  Existing railway 5 mm
  Buildings 12 mm

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CONSTRUCTION LOT LT44 – SINGLE-TRACK TUBES

MONITORING RESULTS

Firste
10 mm
20 mm
30 mm

Linke Ulme
ver.
10 mm
20 mm
5 mm

Rechte Ulme
ver.
10 mm
20 mm
5 mm

hor.

hor.

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CONSTRUCTION LOT LT44 – SINGLE-TRACK TUBES

PHOTOS
CONSTRUCTION LOT LT44 – DOUBLE-TRACK TUBE

CROSS SECTION

• Double-track tube
• Shotcrete lining (min. 35 cm)
• Watertight inner lining (d=55cm)
• Excavation area 129 m²
CONSTRUCTION LOT LT44 – DOUBLE-TRACK TUBE

TYPICAL GEOLOGICAL PROFILES

Geological Profile - Chainage TM 080

Geological Profile - Chainage TM 240
Enlarged Cross Section
CONSTRUCTION LOT LT44 – DOUBLE-TRACK TUBE

EXCAVATION AND SUPPORT

- Excavation subdivided in sidewall galleries and core drive
- Each drive subdivided into several top heading, bench and invert arch
- Round length: Top heading 1.0 m
  Bench 1.0 m
  Invert arch 2.0 m
- Short ring closure distance (max. 8 m behind heading face)
- Min. 35 cm reinforced shotcrete (with 2 layers of wire mesh), temp. side walls min. 30 cm shotcrete
- Application of lattice girder or steel arches (temp. side wall) and forepoling (length 3 – 4 m)
- Face support: Reinforced shotcrete (5-10 cm)
  12 m face bolts (overlap 6 m)
  Support core in top heading
- Underground: Silt/silty sand/Sand
- Max. settlements: Surface 30 mm
  High voltage power line 25 mm
  District heating supply gallery 12 mm
CONSTRUCTION LOT LT44 – DOUBLE-TRACK TUBE

EXCAVATION SEQUENCE – Longitudinal Profile

EXCAVATION SEQUENCE – Plan
CONSTRUCTION LOT LT44 – DOUBLE-TRACK TUBE

EXCAVATION SEQUENCE – Sidewall Galleries

EXCAVATION SEQUENCE – Core Drive

Max. 10 m in 24 h

min. 20 m

Max. 10 m in 24 h

min. 20 m

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CONSTRUCTION LOT LT44 – DOUBLE-TRACK TUBE

Monitoring Results – Sidewall Galleries
CONSTRUCTION LOT LT44 – DOUBLE-TRACK TUBE
CONSTRUCTION LOT LT44 – DOUBLE-TRACK TUBE
CONSTRUCTION LOT LT44 – DOUBLE-TRACK TUBE
CONSTRUCTION LOT LT44 – WIDENING OF DOUBLE-TRACK TUBE

CROSS SECTION

- Double-track tube
- Shotcrete lining (min. 35 cm)
- Watertight inner lining (d=60 cm)
- Excavation area max. 182 m²
- Overburden 10 – 12 m above tunnel crown
CONSTRUCTION LOT LT44 – WIDENING OF DOUBLE-TRACK TUBE

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## COMPARISON OF CALCULATION AND MONITORING RESULTS

<table>
<thead>
<tr>
<th>Settlements/deformations</th>
<th>Calculation results</th>
<th>Monitoring Results</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Excavation U I + U II</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Surface settlements</td>
<td>23 - 31 mm</td>
<td>17 mm</td>
</tr>
<tr>
<td>Settlements in soil above tunnel crown</td>
<td>25 - 37 mm incl. „pre-deformation“</td>
<td>18 mm</td>
</tr>
<tr>
<td>Crown Settlements UI/UII (shotcrete lining)</td>
<td>9 mm</td>
<td>5 mm</td>
</tr>
<tr>
<td><strong>Excavation Core</strong></td>
<td></td>
<td></td>
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<tr>
<td>Surface settlements</td>
<td>55 - 62 mm</td>
<td>32 mm</td>
</tr>
<tr>
<td>Settlements in soil above tunnel crown</td>
<td>24 - 38 mm incl. „pre-deformation“</td>
<td>38 mm</td>
</tr>
<tr>
<td>Crown Settlements Core (shotcrete lining)</td>
<td>10 mm</td>
<td>6 mm</td>
</tr>
</tbody>
</table>
CONSTRUCTION LOT LT44 – CENTRAL CONCRETE PILLAR

Overburden: 12 – 15 m above tunnel crown
CONSTRUCTION LOT LT44 – CENTRAL CONCRETE PILLAR

Trend Kalotte – 0m
Trend Kalotte – 6m
Trend Kalotte – 12m

Firste Mitte
5 mm
5 mm vertikal
horizontal
5 mm horizontal

Rechte Ulme
10 mm vertikal
horizontal
5 mm
CONSTRUCTION LOT LT44 – CENTRAL CONCRETE PILLAR
CONSTRUCTION LOT LT44 – CENTRAL CONCRETE PILLAR
CONSTRUCTION LOT LT44 – CROSSING OF HEATING PIPE

DISTRICT HEATING PIPE

ROHBAChSE

JET GROUTING

GLEISACHSE

OBERFLÄCHE

TUNNELACHSE

2-GLEISIGER TUNNEL

GLEISACHSE

GLEISACHSE

GLEISACHSE

GLEISACHSE

GLEISACHSE

GLEISACHSE

OBERFLÄCHE

OBERFLÄCHE

OBERFLÄCHE

OBERFLÄCHE

OBERFLÄCHE

OBERFLÄCHE

OBERFLÄCHE
CONSTRUCTION LOT LT44 – CROSSING OF HEATING PIPE

FILL
GRAVEL
SAND/SILTY SAND
SILT/CLAYEY SILT
CONSTRUCTION LOT LT44 – CROSSING OF HEATING PIPE
CONSTRUCTION LOT LT44 – CROSSING OF HEATING PIPE

TEIL 1 (44305 – 44317)

Max. Settlements of Heating Pipe
- 8 mm after Sidewall Gallery I
- total 13 mm after Sidewall Gallery II
- total 24 mm after excavation of top heading Core
- total 28 mm after invert excavation

Max. Settlements of Heating Pipe

Settlement Trough along Heating Pipe
CONSTRUCTION LOT LT44 – CROSSING OF HEATING PIPE
CONSTRUCTION LOT LT44 – CROSSING OF HEATING PIPE

23/08/2006 10:45
CONSTRUCTION LOT LT44 – EXCAVATION UNDER HIGH VOLTAGE CABLES

FILL
GRAVEL
SAND/SILTY SAND
SILT/CLAYEY SILT

JET GROUTING OF SAND AND GRAVEL LAYERS

DONAULÄNDEBAHN

380kV-Leitung

10 m
11.5 m

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CONSTRUCTION LOT LT44 – EXCAVATION UNDER HIGH VOLTAGE CABLES

SETTLEMENT/HEAVE

HEAVE DUE TO JET GROUTING

CURVATURE

max. curvature:
0.0008 = 1/R = 1/1250
CONSTRUCTION LOT LT44 – GEOTECHNICAL MONITORING

• Spacing of monitoring sections max. 10 m
• Daily readings at least up to 30 m behind excavation face

• Settlement monitoring in heating supply line
• Sub-surface targets installed on power line
CONSTRUCTION LOT LT44 – INSITU CONCRETE LINING
GEOTECHNICAL MONITORING:

- surface settlements (buildings, utilities, railway tracks, roads, etc.)
- displacements of tunnel lining
- level of shotcrete loading (by analyses based on deformation monitoring)
- extensometer
- tunnel face monitoring (without reflectors)
- vibration monitoring
CONSTRUCTION LOT LT44 – GEOTECHNICAL MONITORING

+ automatic monitoring from fixed monitoring stations (measurements every 15 min)
+ if monitoring results exceed defined alarm levels → alarm by SMS
CONSTRUCTION LOT LT44 – GEOTECHNICAL MONITORING

MONITORING OF EXCAVATION FACE DISPLACEMENTS

+ automatic monitoring of face displacements without reflectors

+ monitoring of 30 spots (measurements every 5 minutes).

+ if monitoring results exceed defined alarm levels
  → alarm by SMS
CONSTRUCTION LOT LT44 – GEOTECHNICAL MONITORING

Horizontal cracks

Horizontal cracks
CONSTRUCTION LOT LT44 – GEOTECHNICAL MONITORING

Dia.: LT41 Lannenstraße
Section: Diagonal Y/Y
Customer: ÖBB Infrastruktur Bau AG
Elevation: Streckenführung
Epoch: 2007-11-06T05:00
Remark: 

CONSTRUCTION LOT LT44 – TRACK SUPERSTRUCTURE

COMPLETION OF LAINZER TUNNEL IN 2012