Design, manufacturing and installation of segmental lining in TBM tunnels


Johannes Gollegger, Technical Manager EPC TBM Follo Line Project
Typical cross sections

Follo Line Tunnel
Norway

Wienerwald Tunnel
(Austria)
Gewölbebeton norm. 35cm
cast in situ lining 35cm
Segmentauskleidung 30cm
segmental lining 30cm

Kaiser-Wilhelm Tunnel
Germany
Stahlbetonstichung 40cm
gasket sealed segmental lining 40cm
Bautechn. Nutzraum 30cm
space for interventions 30cm
Introduction

Ring geometry
- Ring consists of 4 to 8 segments
- Tunnel diameter
- Max. permissible size of segments for intended transport
- Mechanical mechanisms for installing segments by erector
- Number of thrust jacks and their distribution over the ring
- Optimization according to project specific factors

Ring conicity
- Tunnel alignment – min curve radius
- Water tightness
Swiss strut lining

- Ring consists of 6 segments
- No bolts or dowels
- No gasket
- Key stone always at the bottom
- Especially used for project with low requirements to segmental lining (double shell lining)
Hexagonal ring (Honeycomb)

- Ring consists of 4 segments
- Especially used for hydropower projects (i.e. headrace tunnel)
- The joints are not planar, but convex/concave
Left and right ring

Type 2a
Type 3
Type 1a
Type 2b
Type 1a
Type 1b
Type Fl
Universal ring
Ring conicity

\[ \frac{b_m}{R} = \frac{K}{D_a} \]

- \( K \) = conicity
- \( b_m \) = mean ring width
- \( R \) = tunnel radius
- \( D_a \) = outer diameter

Parallel segment

Honeycomb segment

Asymmetric tapered segment

Symmetric tapered segment
Joint design – groove and tongue systems
Gaskets – glued and anchored
Gaskets – performance
Design requirements – Follo Line Project

- The surface roughness of the moulds shall not exceed 70 µm
- Only cement based distance ‘spacers’ shall be permitted
- Temperature of fresh concrete maximum 30°C
- Temperature during curing maximum 55°C
- Direct steam curing is not accepted, only warm air back-pressure
- Temperature gradient during curing maximum 10°C / h
- Temperature difference between uncured segment and air maximum 15°C
- Any cast-in holes, either for lifting or grouting, shall be ‘blind holes’ (not drilled through the entire segment – max pocket depth 150mm)
- All segments shall be stacked intrados up
A combination of steel bars, wire mesh and steel fibres may be used. However, the minimum reinforcement requirement shall be provided by steel bars.

- For fire protection PP-fibres shall be added.
- The maximum allowed concrete grade is B55.
- The use of suitable excavated muck for segment production to be maximised.
- Trial assembly to be performed.
Tolerances

- Circumferential lengths \(+/- 0.6 \text{ mm}\)
- Segment thickness \(+3 \text{ mm} / -1.5 \text{ mm}\)
- Width \(+/- 0.5 \text{ mm}\)
- Joint plane of circumferential joint \(+/- 0.5 \text{ mm}\)
- Joint plane of radial joint face \(+/- 0.5 \text{ mm}\)
- Depth of gasket sealing grooves \(+0.2 \text{ mm} / -0.0 \text{ mm}\)
- Width of gasket sealing groove max deviation \(+0.2 \text{ mm} / -0.0 \text{ mm}\)
- Distance from inner edge of segment to gasket sealing groove max deviation \(+/- 1 \text{ mm}\)
- Rotation of radial joint face across element centre plain parallel to inner face \(+/- 0.3 \text{ mm}\)
- Rotation of radial joint face across element centre plain perpendicular to inner face \(+/- 0.5 \text{ mm}\)
Segmental lining – Follo Line Project
Erector cone, re-grouting socket and segment marking
Standard bolt and biblock connector
Rig area Åsland 31. mai 2016

1. Tunnelportal
2. Transportbånd
3. Massehåndtering
4. Knuseverk
5. Betongfabrikk
6. Elementfabrikk
7. Lagerområde for elementer
8. Kontorrigg
9. Boligrigg
Rig area Åsland 31. mai 2016
Rig area Åsland 31. mai 2016
Overview of segment factory
Cleaing of mould
Installation of inserts
Finalisation
Concreting
Mould on the way the curing chamber
Moulds leaving the curing chamber
Rotation of segment
Inspection of segment
Intermediate segment storage
Segment details
Installation of segmental ring

- Longitudinal joints
- TBM hydraulic jacks
- TBM shield
- Circumferential joints
- Packers

Assembly of the Ring\001.jpeg
Installation of segmental ring

RING POSITION 1

RING POSITION 2
Installation of segmental ring

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<th>RING COMBINATIONS POSSIBLE - RING POSITION</th>
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Thank you very much for your attention!