

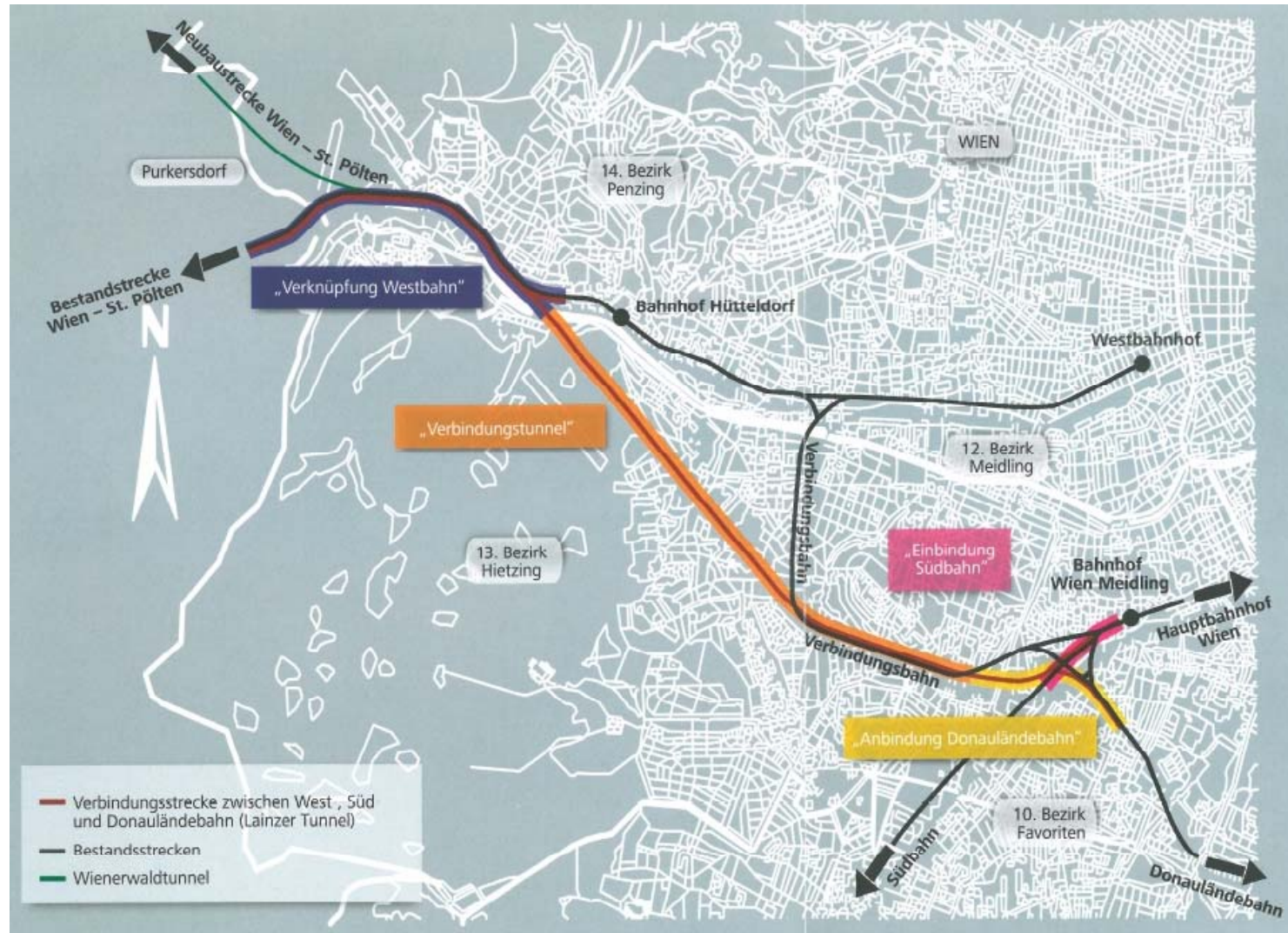


DESIGN AND CONSTRUCTION OF LARGE TUNNELS IN SOIL AND FAULTED ROCK

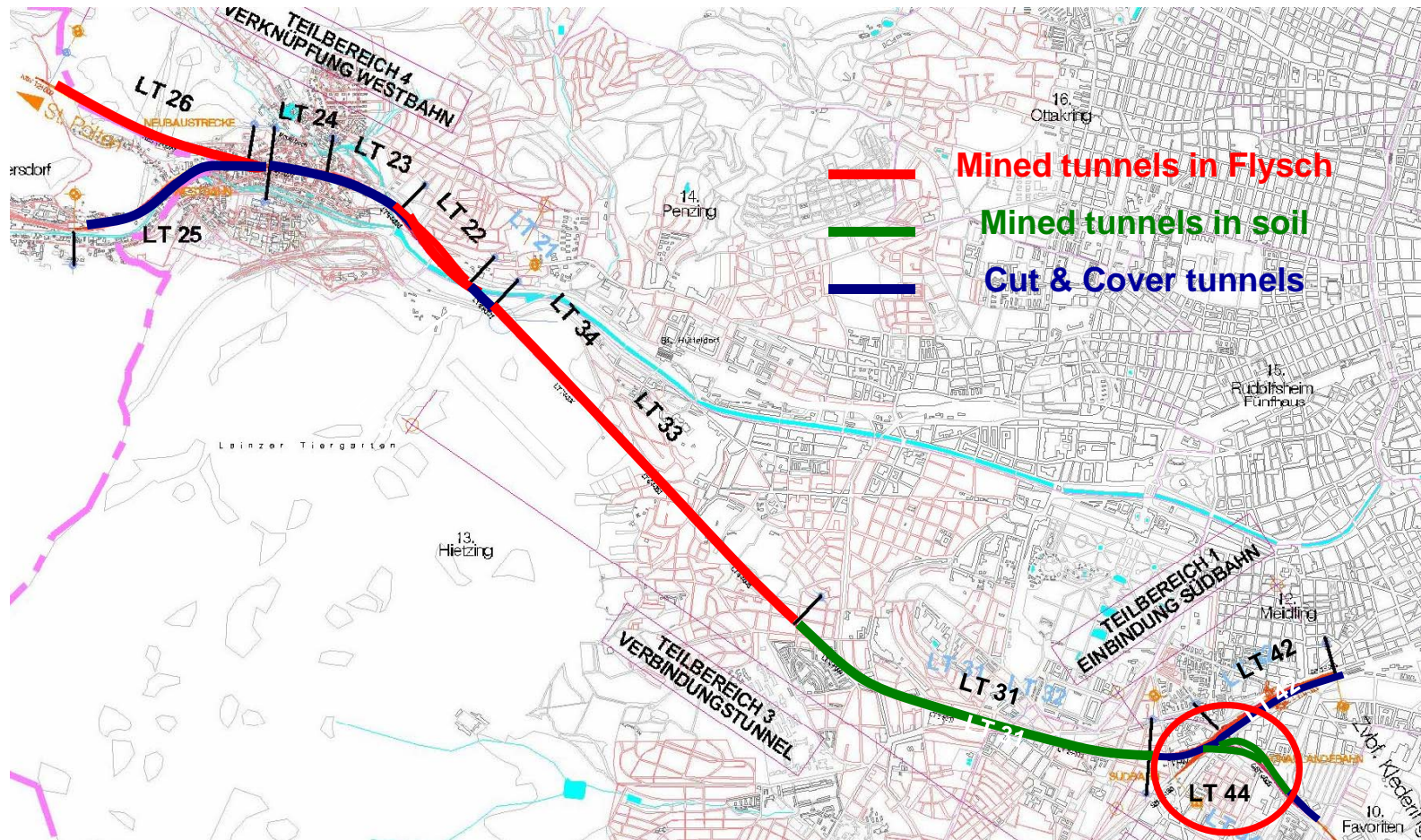
LAINZER TUNNEL PROJECT

Josef Daller, iC consultants, Vienna - Austria

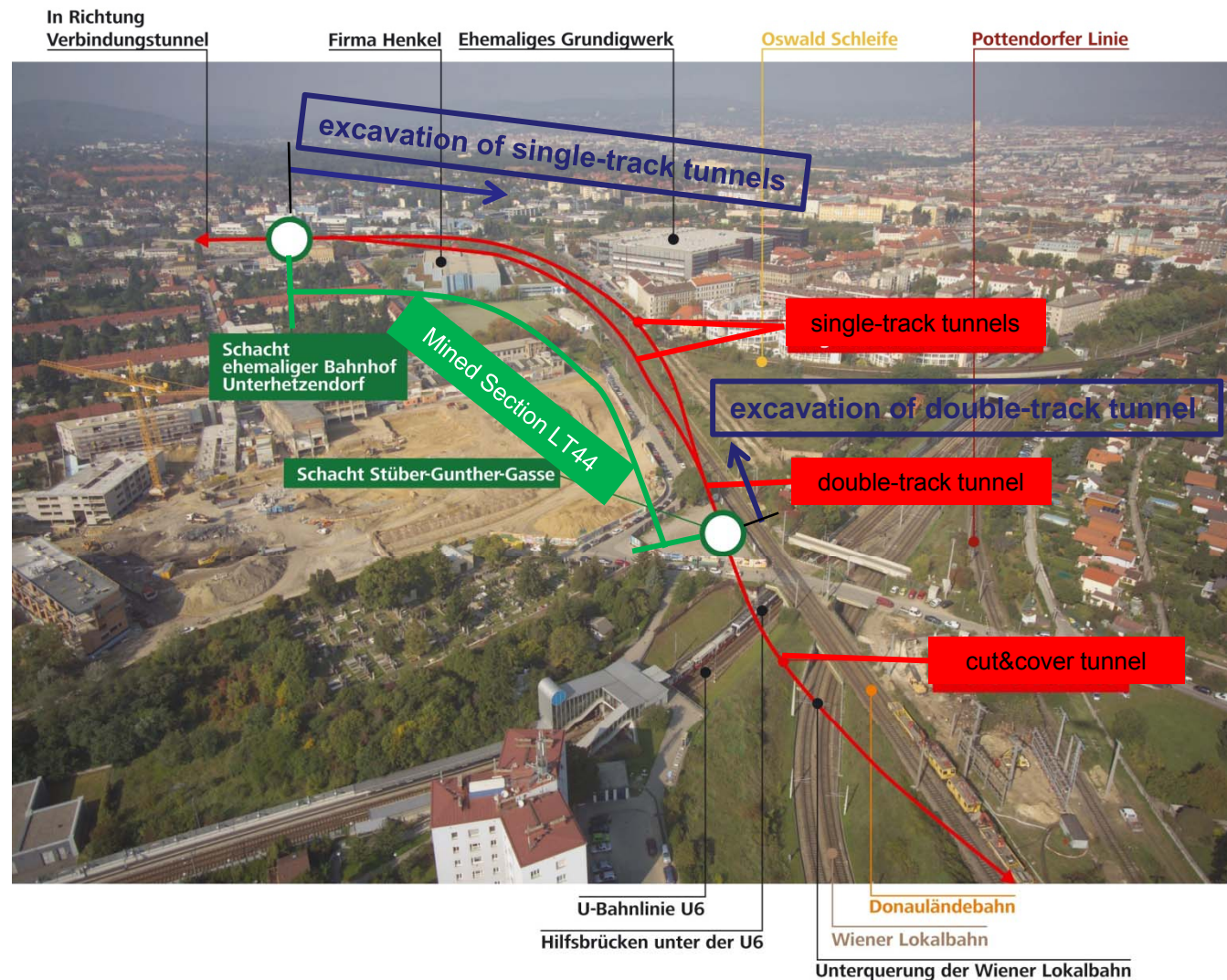
LAINZER TUNNEL PROJECT



LAINZER TUNNEL PROJECT



LAINZER TUNNEL PROJECT – CONSTRUCTION LOT LT44



CONSTRUCTION LOT LT44 - OVERVIEW

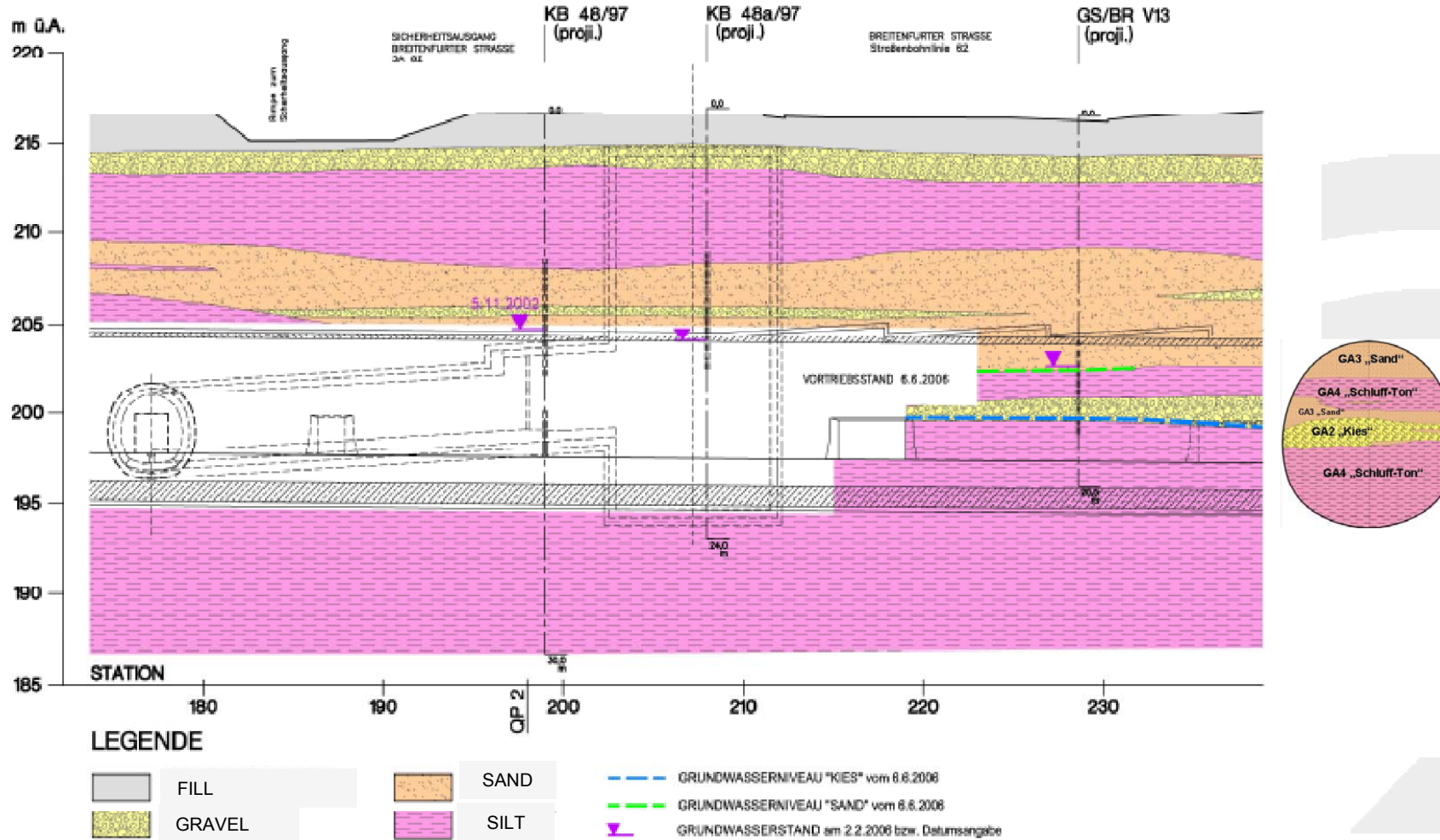
- **2 starting shafts**
- **957,4 m single-track tubes with about 84 m² excavation cross section**
- **128,5 m double-track tube with about 129 m² excavation cross section**
- **110,9 m widening of double track tube to maximum 182 m² in 3 steps**
- **89 m special section with concrete pillar at transition 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



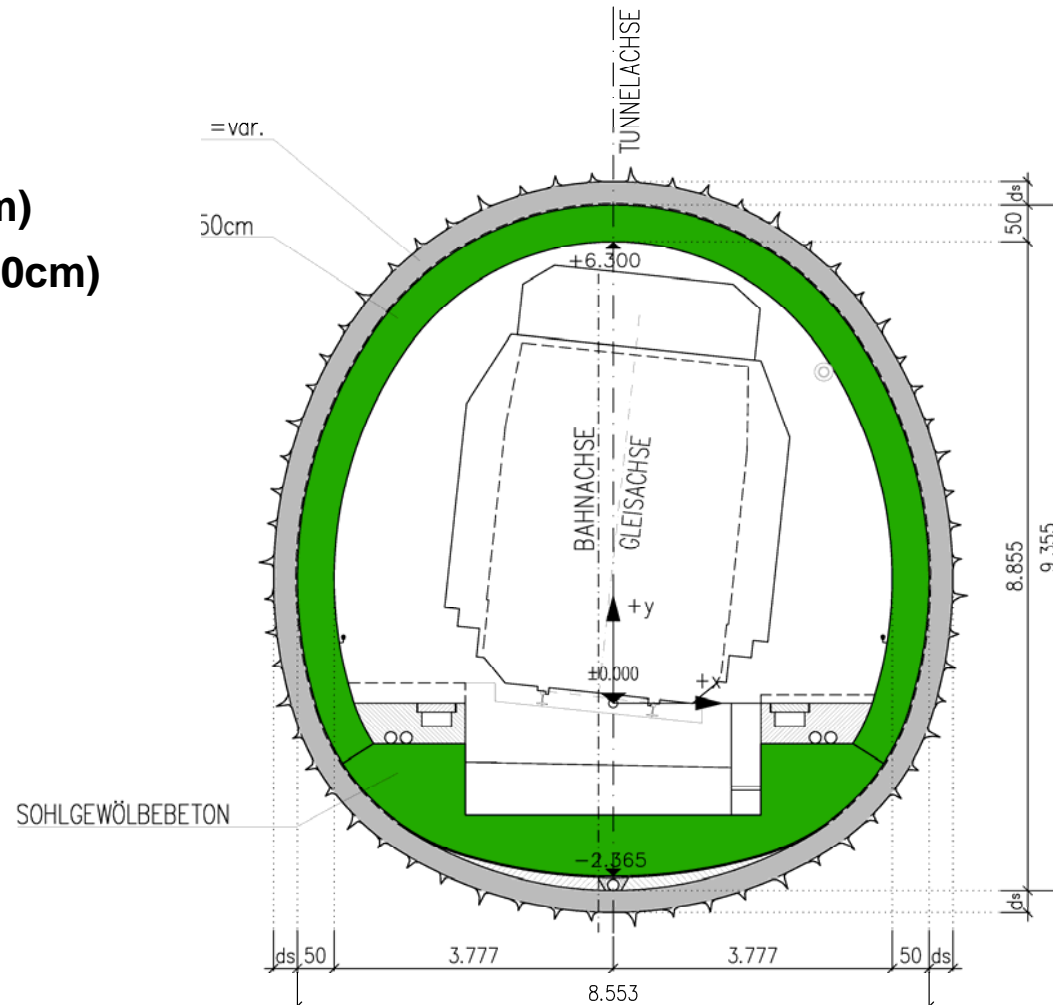
CONSTRUCTION LOT LT44 – SOIL PARAMETER FOR FE-ANALYSES

Type of Soil	Friction Angle	Cohesion	Unit weight/ Unit weight under bouyancy	void ratio	Young`s Modulus first loading	Young`s Modulus unloading/reloading	Poisson Ratio	Permeability
	φ	c	γ/γ'	e	E_1	E_2	v	k
	[°]	[kN/m ²]	[kN/m ³]	[-]	[MN/m ²]	[MN/m ²]	[-]	[m/s]
Fill material	25	5	20/10	0,65	15	30	0,37	-
Gravel	35	5	22/12	0,38	130	200	0,30	1x10 ⁻³
Silty Sand	30	10	21,5/11,5	0,43	80	120	0,33	5x10 ⁻⁵
Clayey Silt/Silt	20	40	20,5/10,5	0,67	35	60	0,40	1x10 ⁻⁸

CONSTRUCTION LOT LT44 – SINGLE-TRACK TUBES

CROSS SECTION

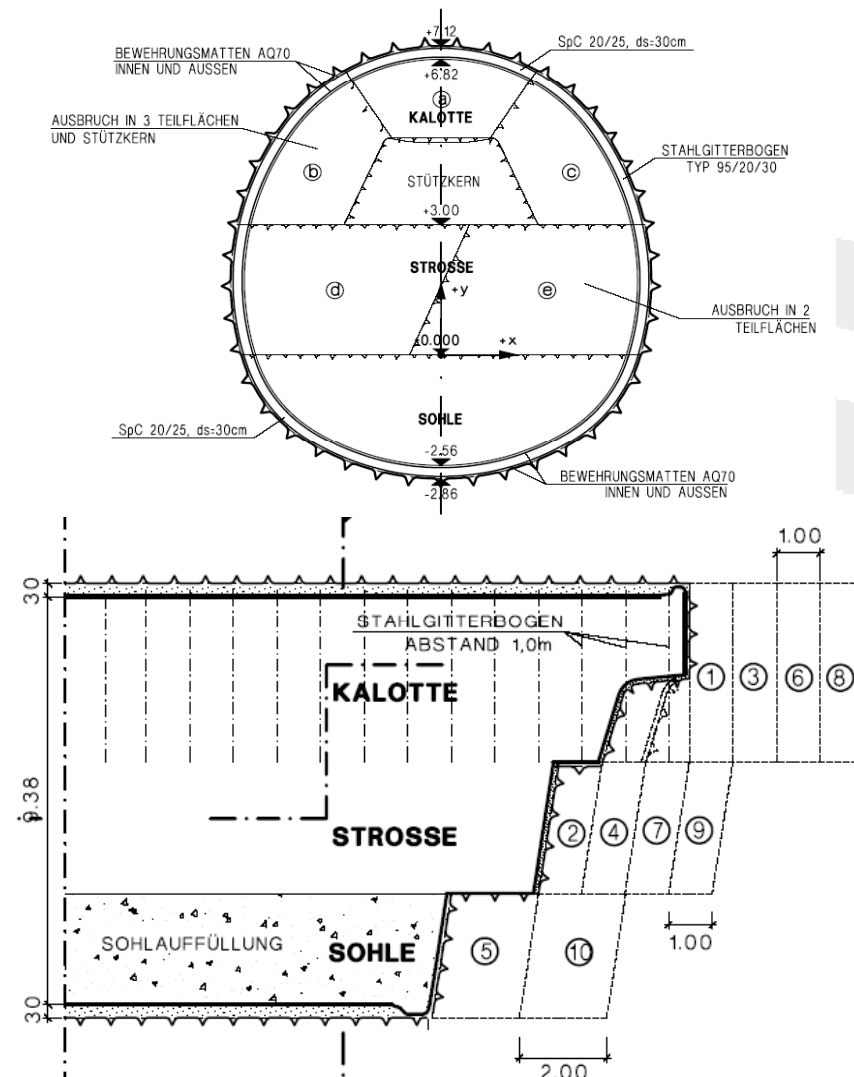
- Single-track tube
- Shotcrete lining (min. 30 cm)
- Watertight inner lining (d=50cm)
- Excavation area 84 m²



CONSTRUCTION LOT LT44 – SINGLE-TRACK TUBES

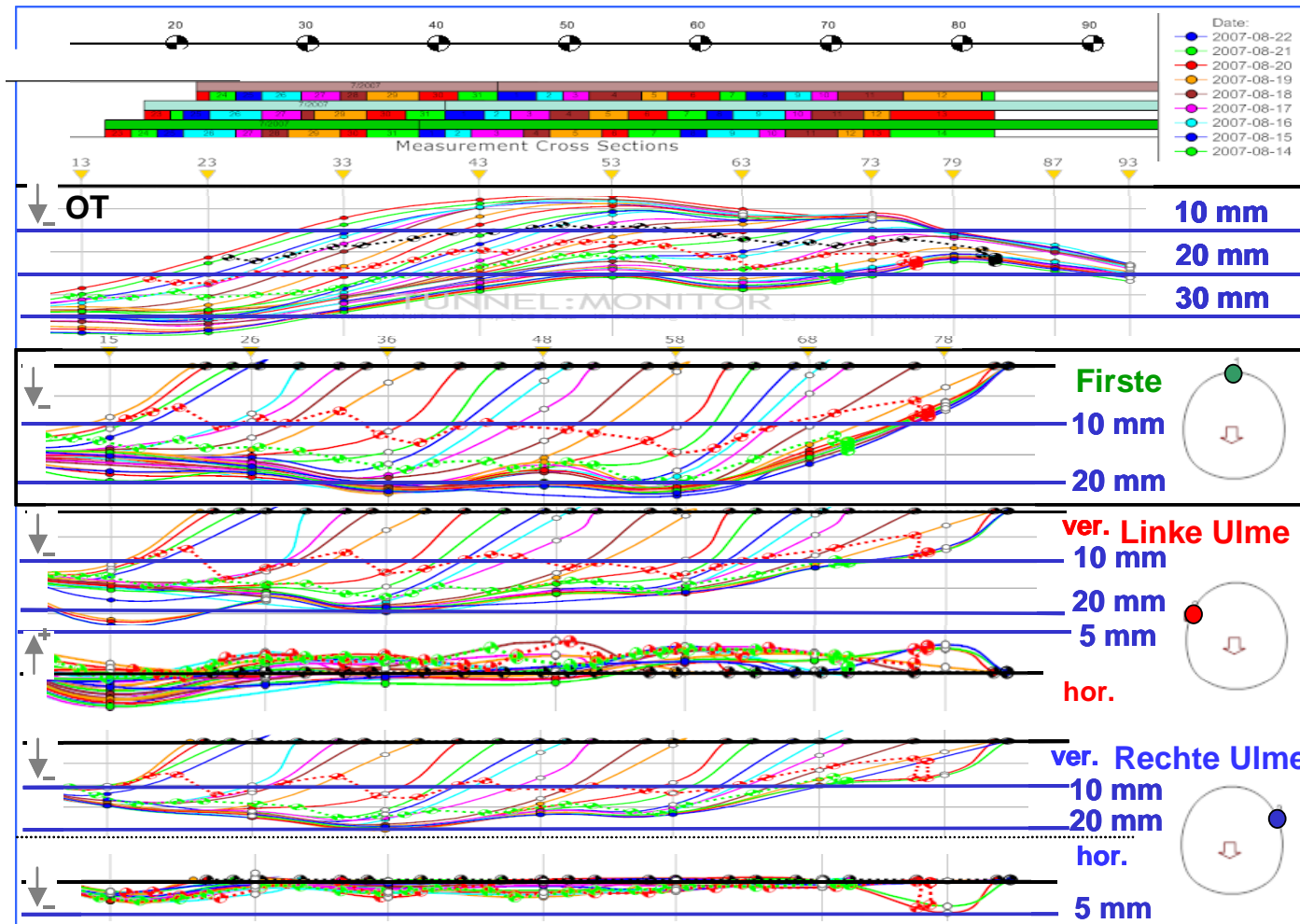
EXCAVATION AND SUPPORT

- 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



CONSTRUCTION LOT LT44 – SINGLE-TRACK TUBES

MONITORING RESULTS



CONSTRUCTION LOT LT44 – SINGLE-TRACK TUBES

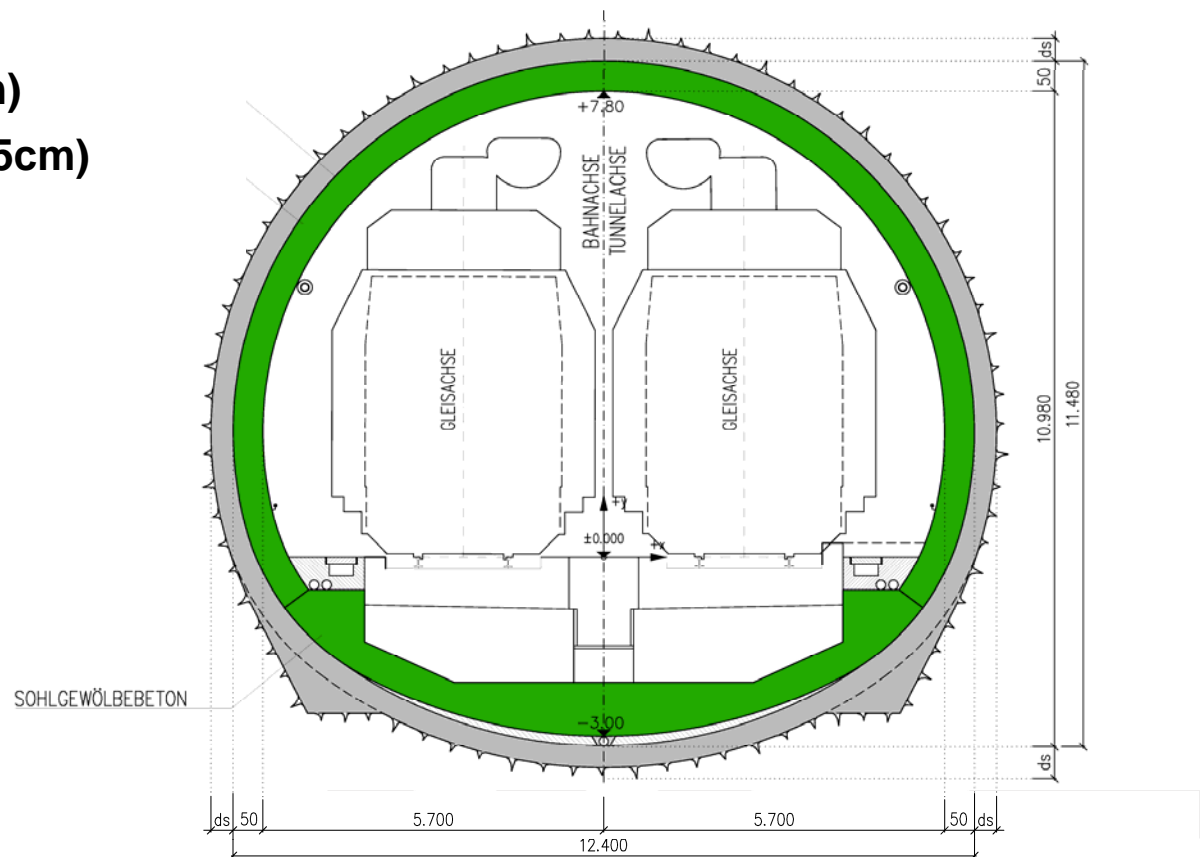
PHOTOS



CONSTRUCTION LOT LT44 – DOUBLE-TRACK TUBE

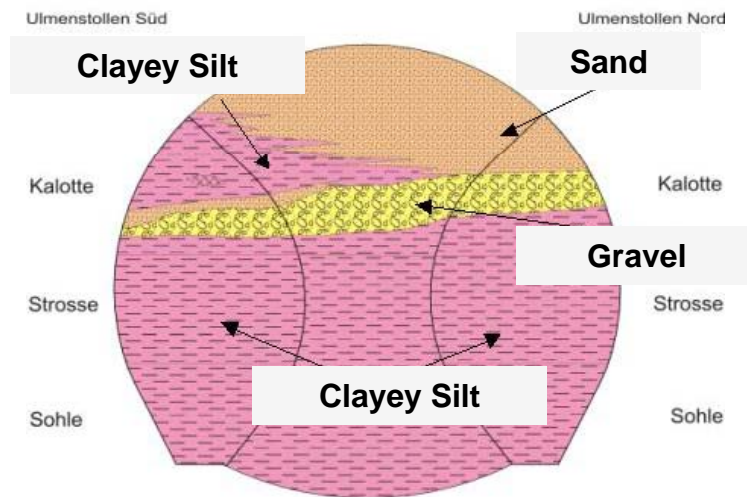
CROSS SECTION

- Double-track tube
- Shotcrete lining (min. 35 cm)
- Watertight inner lining (d=55cm)
- Excavation area 129 m²

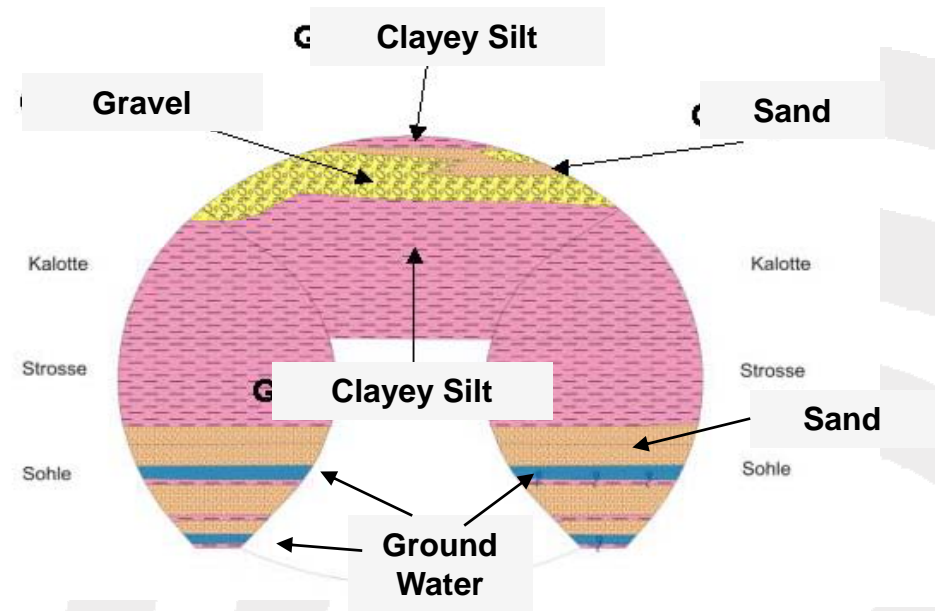


CONSTRUCTION LOT LT44 – DOUBLE-TRACK TUBE

TYPICAL GEOLOGICAL PROFILES



Geological Profile - Chainage TM 080

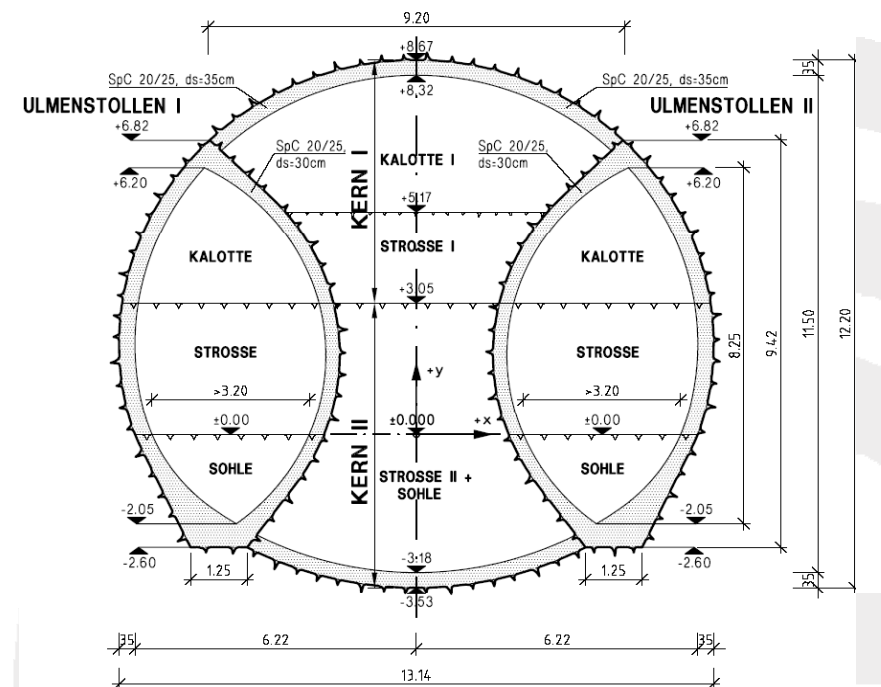


Geological Profile - Chainage TM 240
Enlarged Cross Section

CONSTRUCTION LOT LT44 – DOUBLE-TRACK TUBE

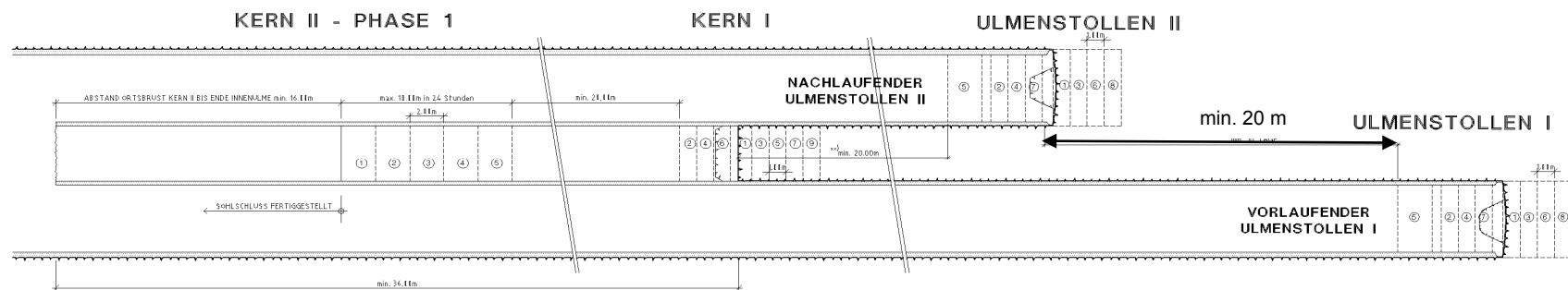
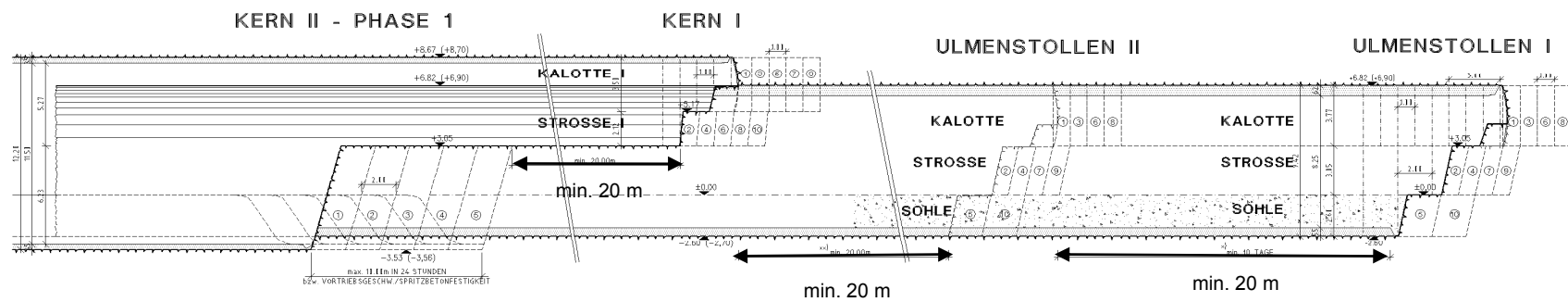
EXCAVATION AND SUPPORT

- 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. 35cm 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



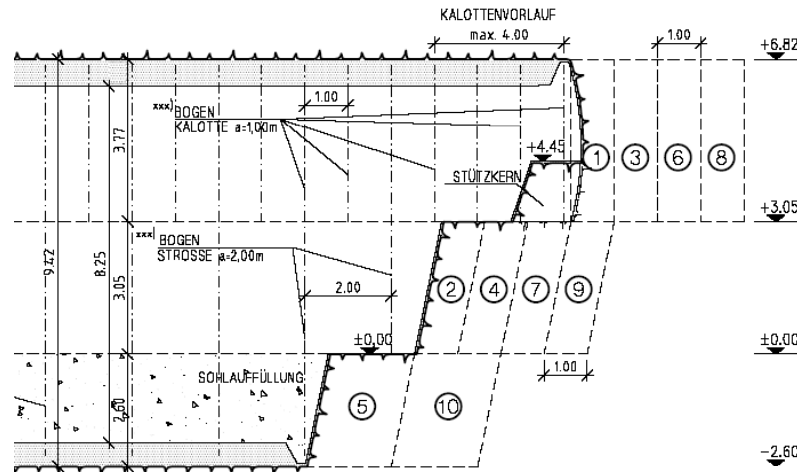
CONSTRUCTION LOT LT44 – DOUBLE-TRACK TUBE

EXCAVATION SEQUENCE – Longitudinal Profile

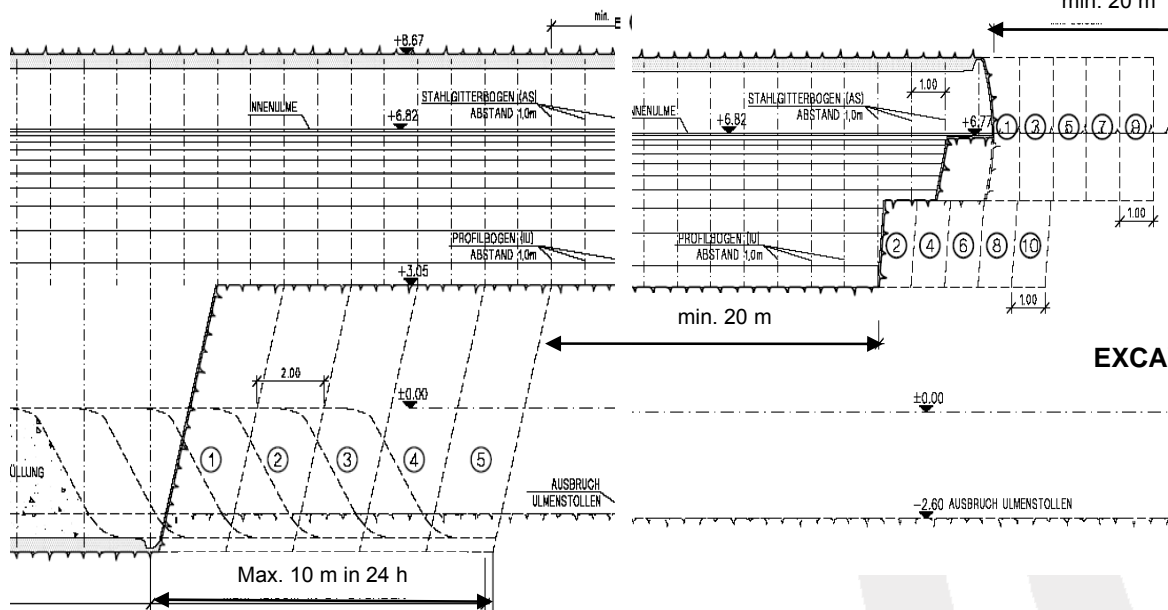


EXCAVATION SEQUENCE – Plan

CONSTRUCTION LOT LT44 – DOUBLE-TRACK TUBE



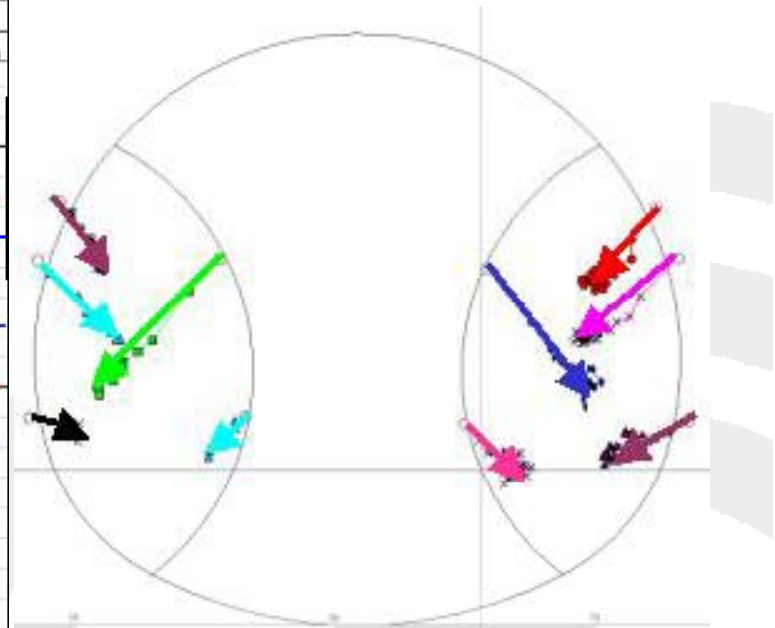
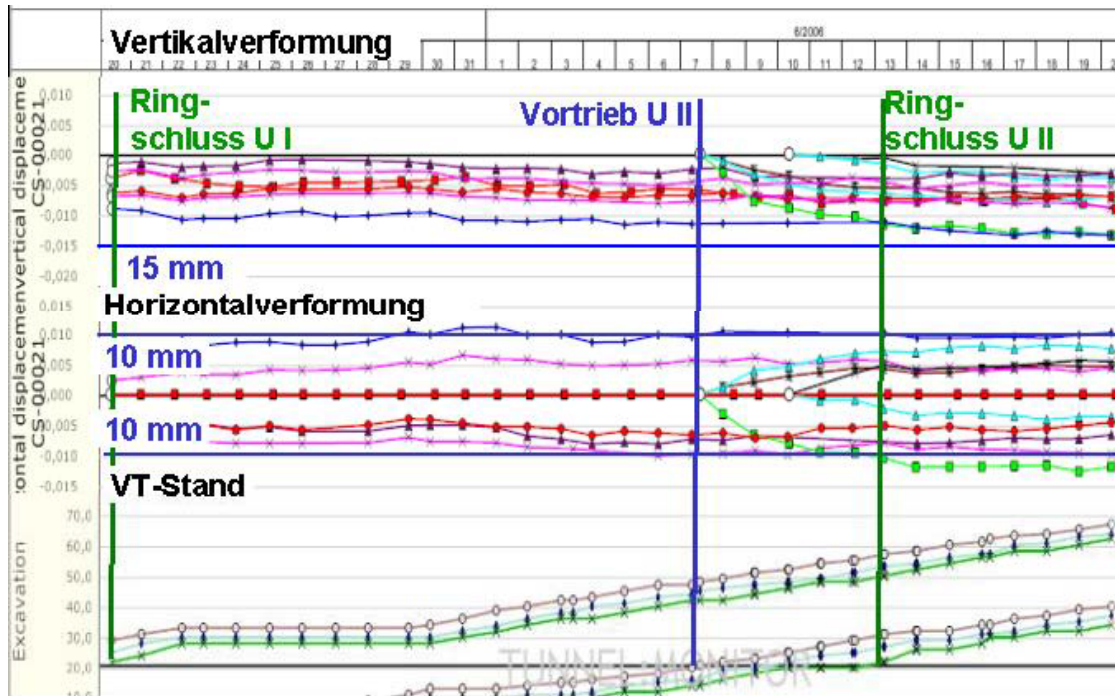
EXCAVATION SEQUENCE – Sidewall Galleries



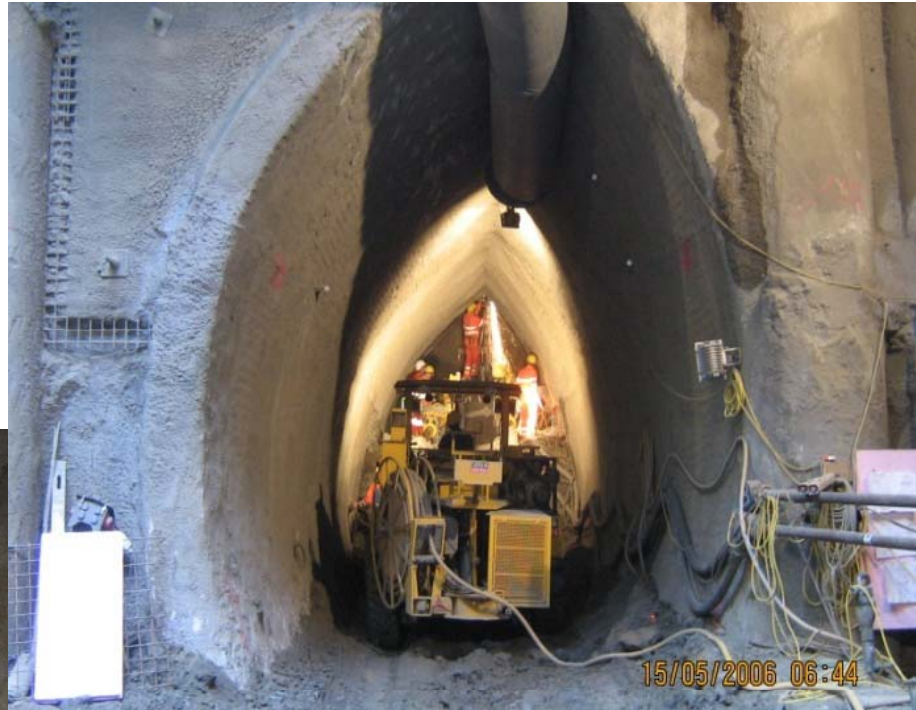
EXCAVATION SEQUENCE – Core Drive

CONSTRUCTION LOT LT44 – DOUBLE-TRACK TUBE

Monitoring Results – Sidewall Galleries



CONSTRUCTION LOT LT44 – DOUBLE-TRACK TUBE



CONSTRUCTION LOT LT44 – DOUBLE-TRACK TUBE



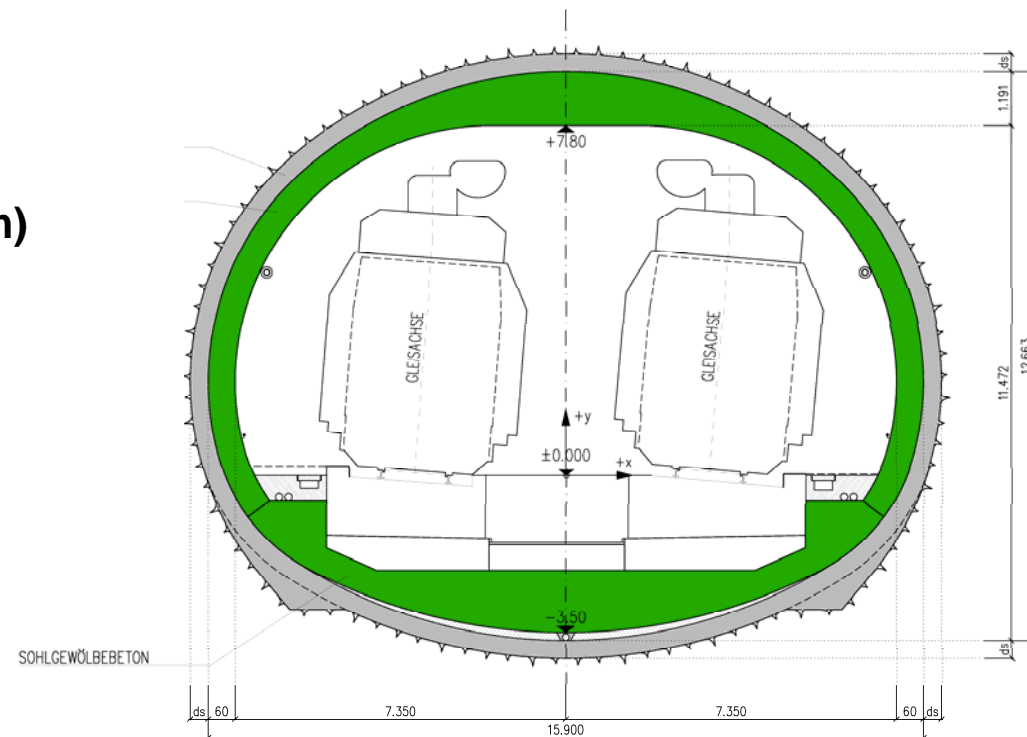
CONSTRUCTION LOT LT44 – DOUBLE-TRACK TUBE



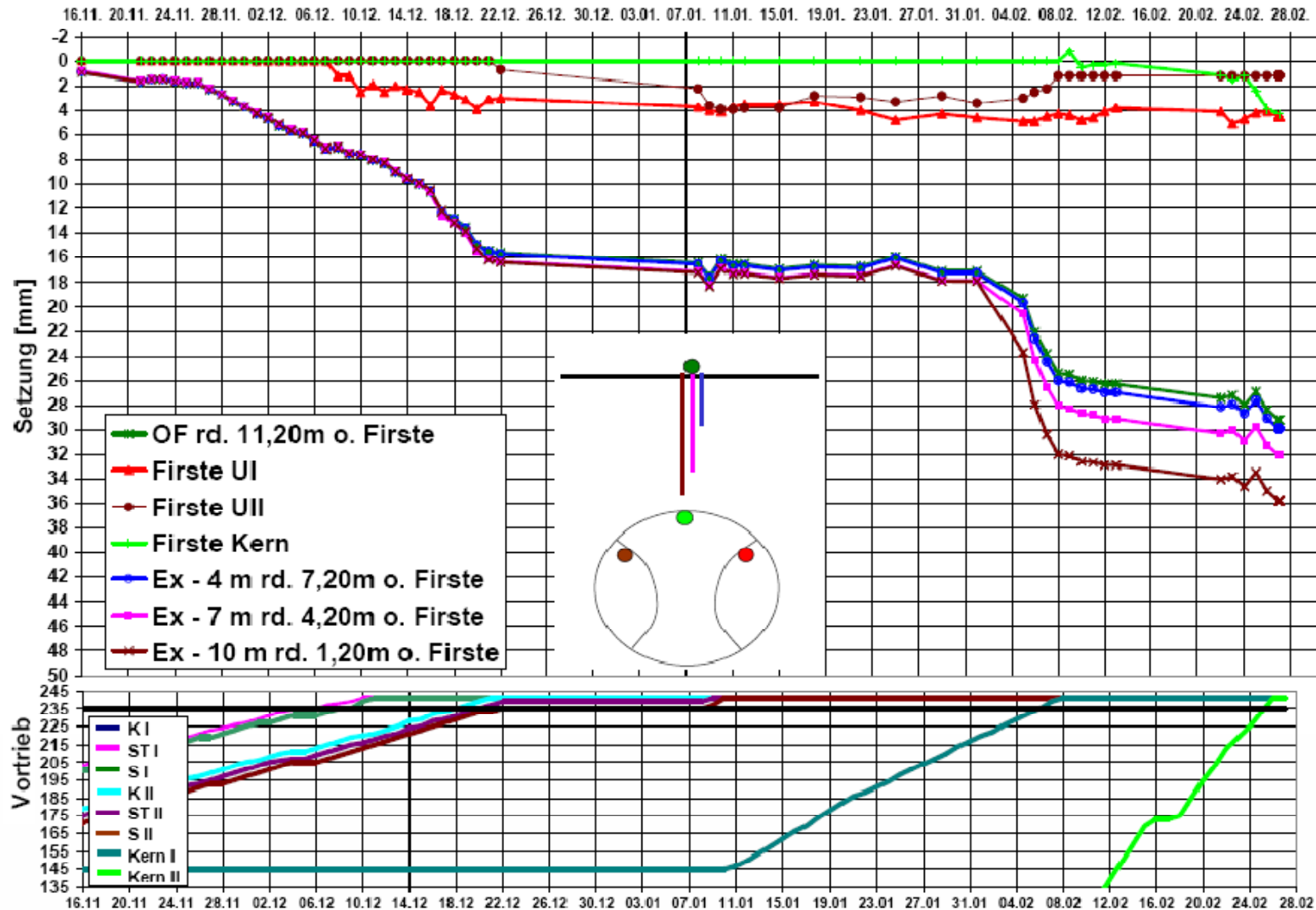
CONSTRUCTION LOT LT44 – WIDENING OF DOUBLE-TRACK TUBE

CROSS SECTION

- Double-track tube
- Shotcrete lining (min. 35 cm)
- Watertight inner lining (d=60cm)
- Excavation area max. 182 m²
- Overburden 10 – 12 m above tunnel crown



CONSTRUCTION LOT LT44 – WIDENING OF DOUBLE-TRACK TUBE

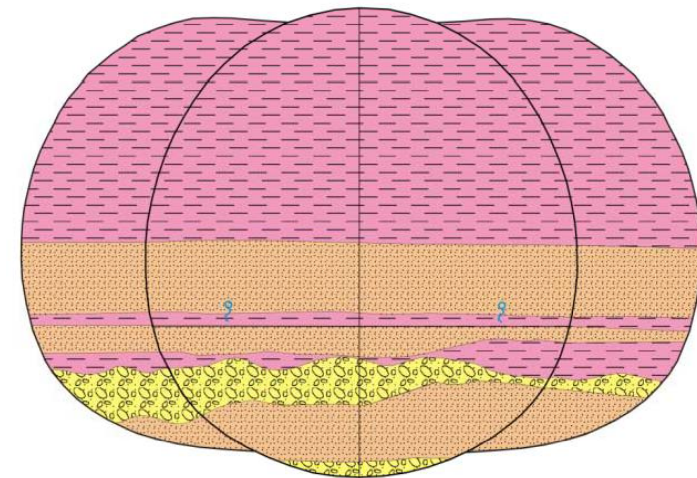
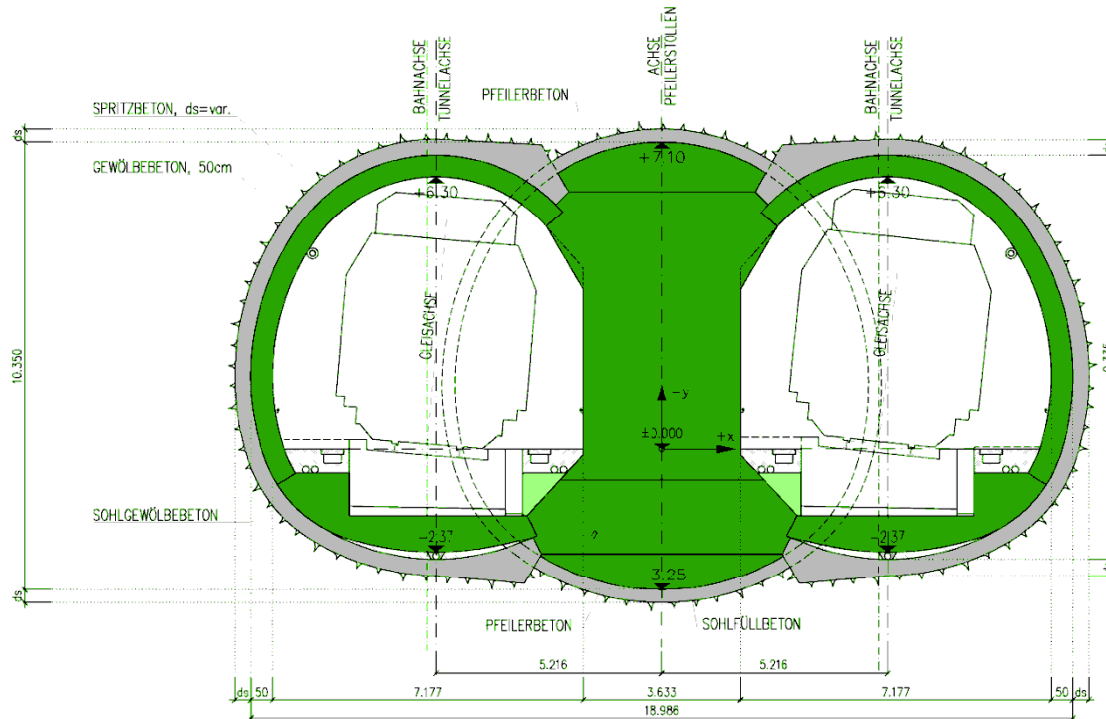


CONSTRUCTION LOT LT44 – WIDENING OF DOUBLE-TRACK TUBE

COMPARISON OF CALCULATION AND MONITORING RESULTS

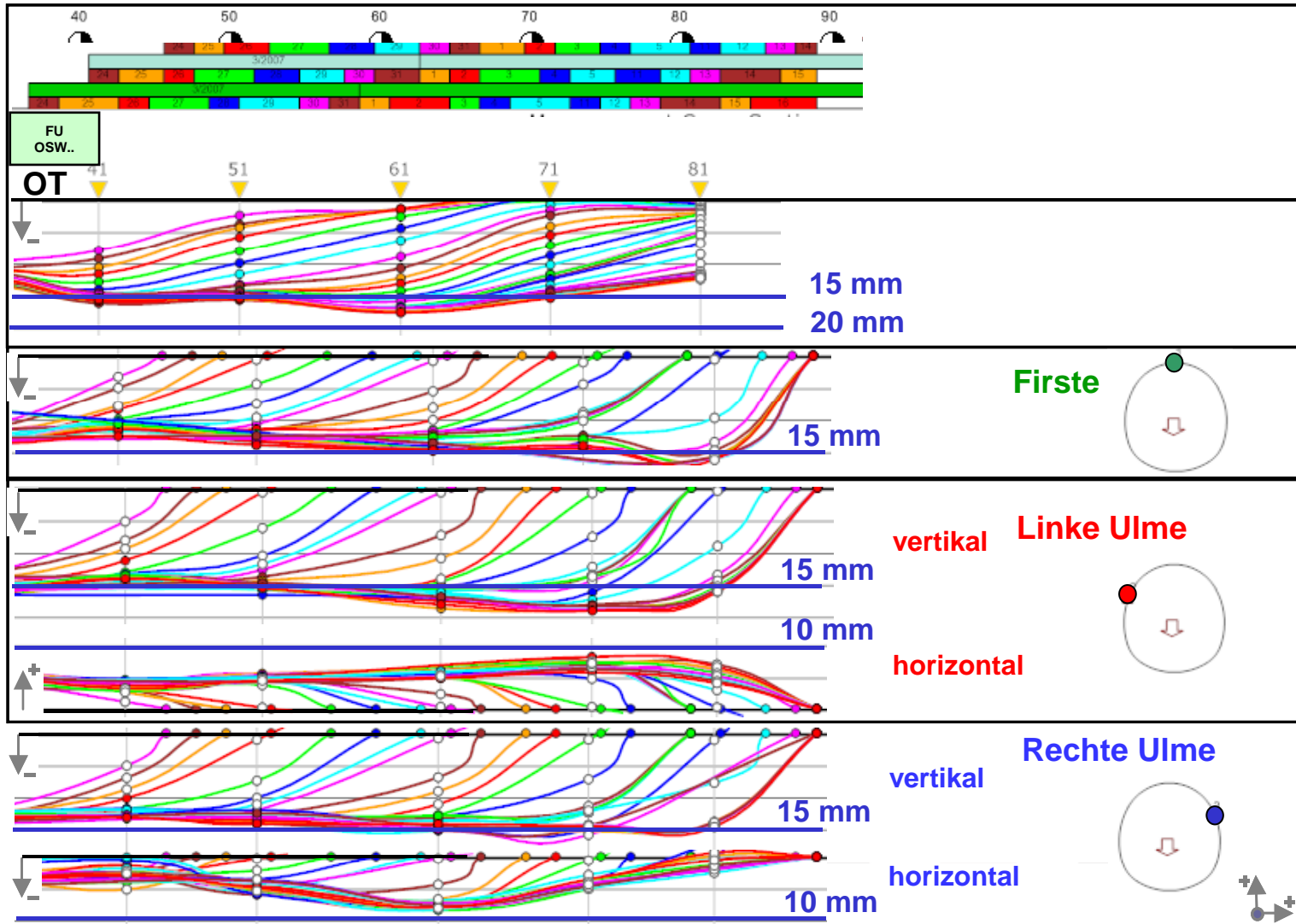
Settlements/deformations	Calculation results	Monitoring Results
Excavation U I + U II		
Surface settlements	23 - 31 mm	17 mm
Settlements in soil above tunnel crown	25 - 37 mm incl. „pre-deformation“	18 mm
Crown Settlements UI/UII (shotcrete lining)	9 mm	5 mm
Excavation Core		
Surface settlements	55 - 62 mm	32 mm
Settlements in soil above tunnel crown	24 - 38 mm incl. „pre-deformation“	38 mm
Crown Settlements Core (shotcrete lining)	10 mm	6 mm

CONSTRUCTION LOT LT44 – CENTRAL CONCRETE PILLAR

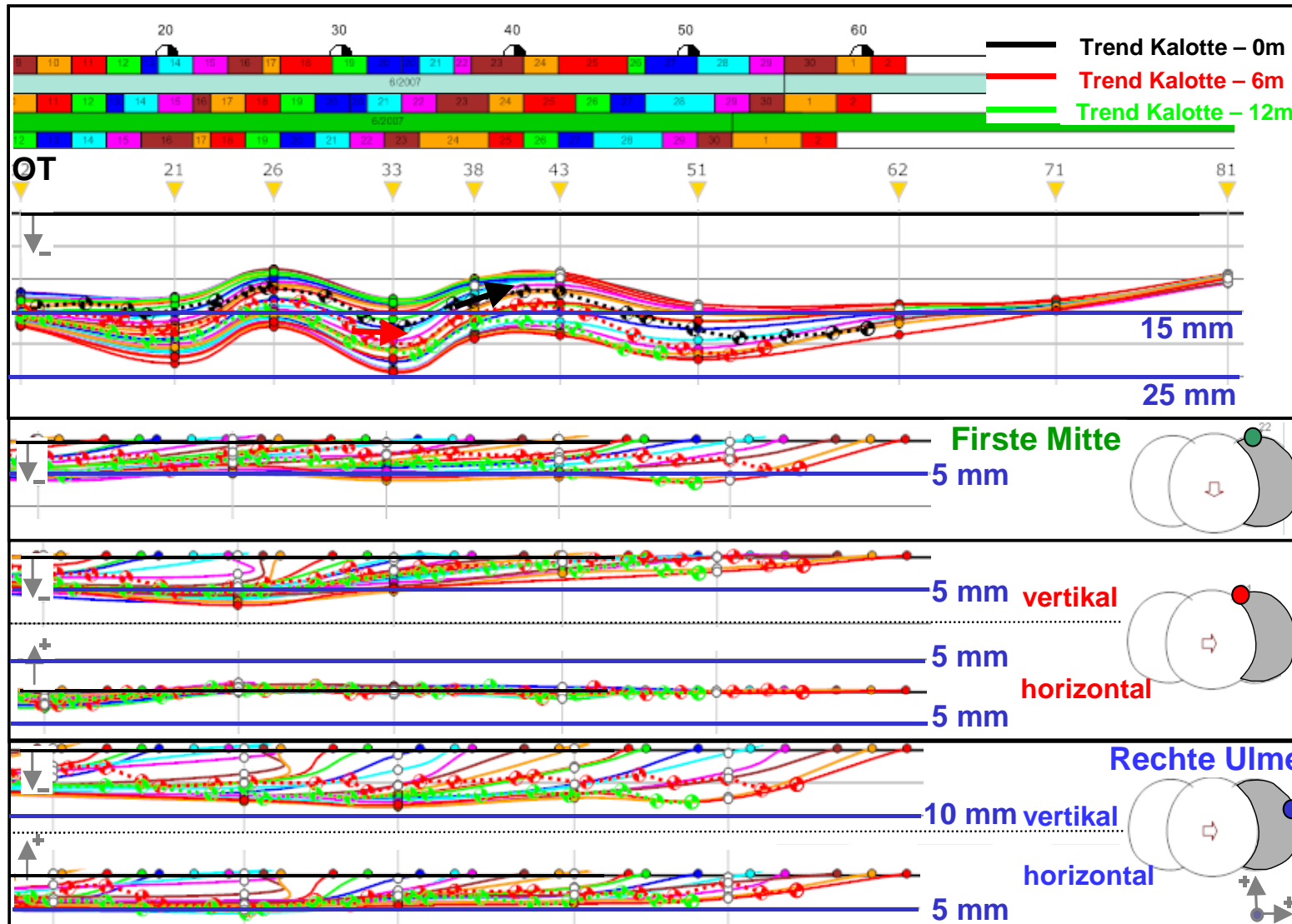


Overburden: 12 – 15 m above tunnel crown

CONSTRUCTION LOT LT44 – CENTRAL CONCRETE PILLAR



CONSTRUCTION LOT LT44 – CENTRAL CONCRETE PILLAR



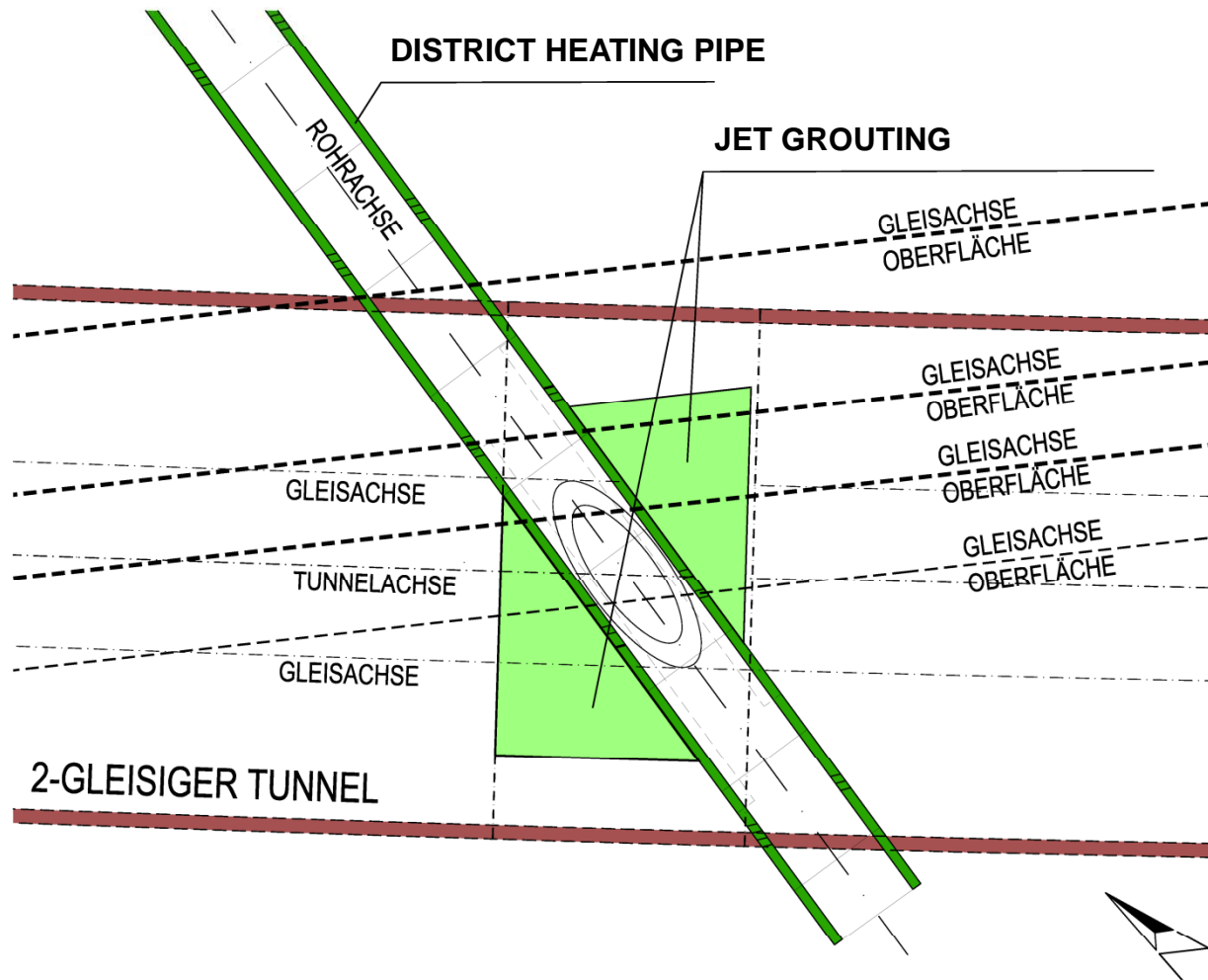
CONSTRUCTION LOT LT44 – CENTRAL CONCRETE PILLAR



CONSTRUCTION LOT LT44 – CENTRAL CONCRETE PILLAR

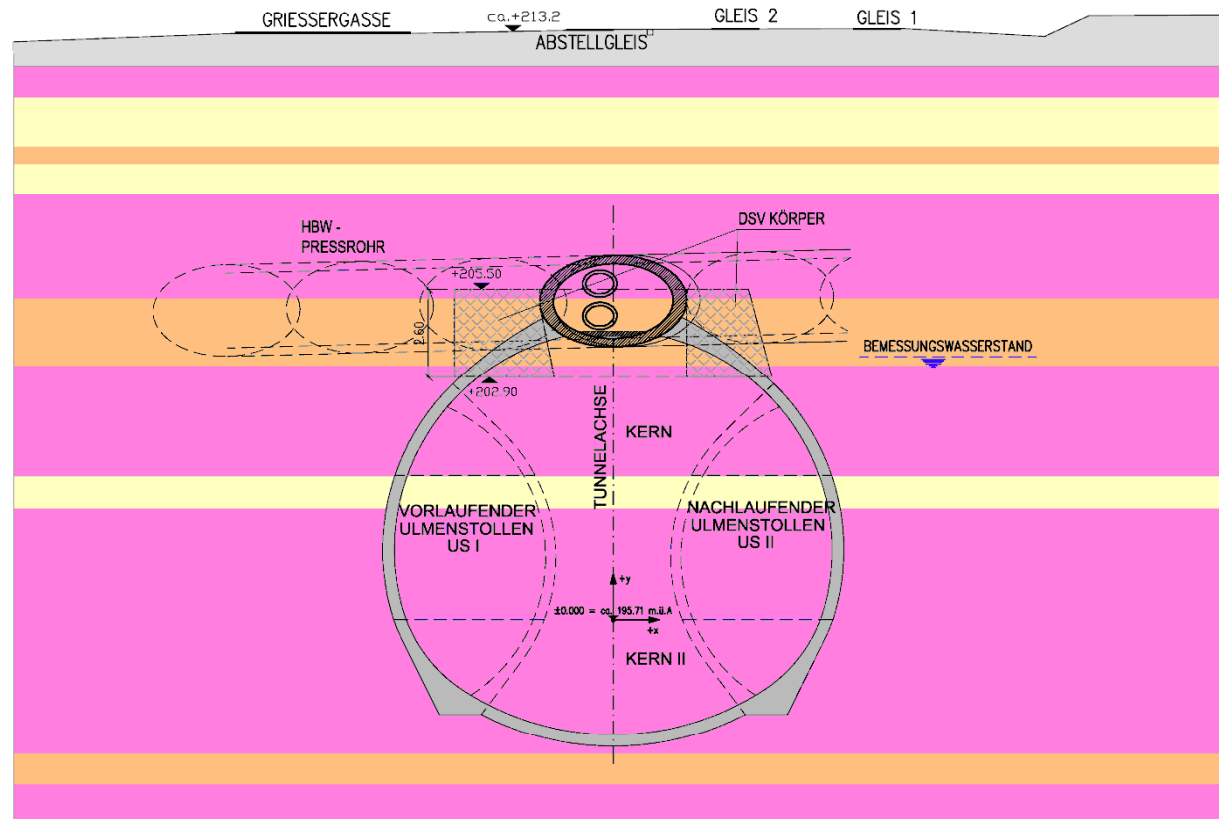


CONSTRUCTION LOT LT44 – CROSSING OF HEATING PIPE

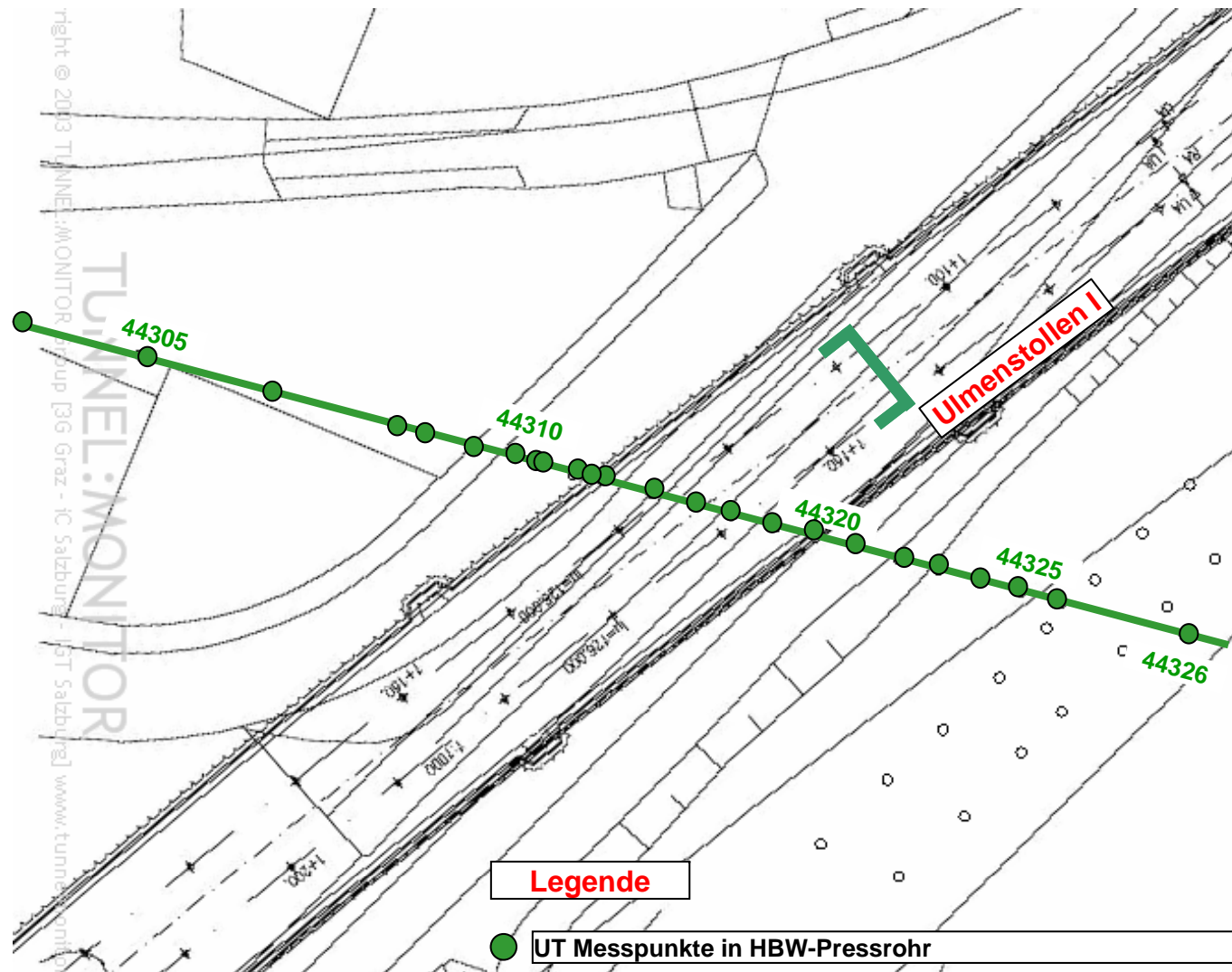


CONSTRUCTION LOT LT44 – CROSSING OF HEATING PIPE

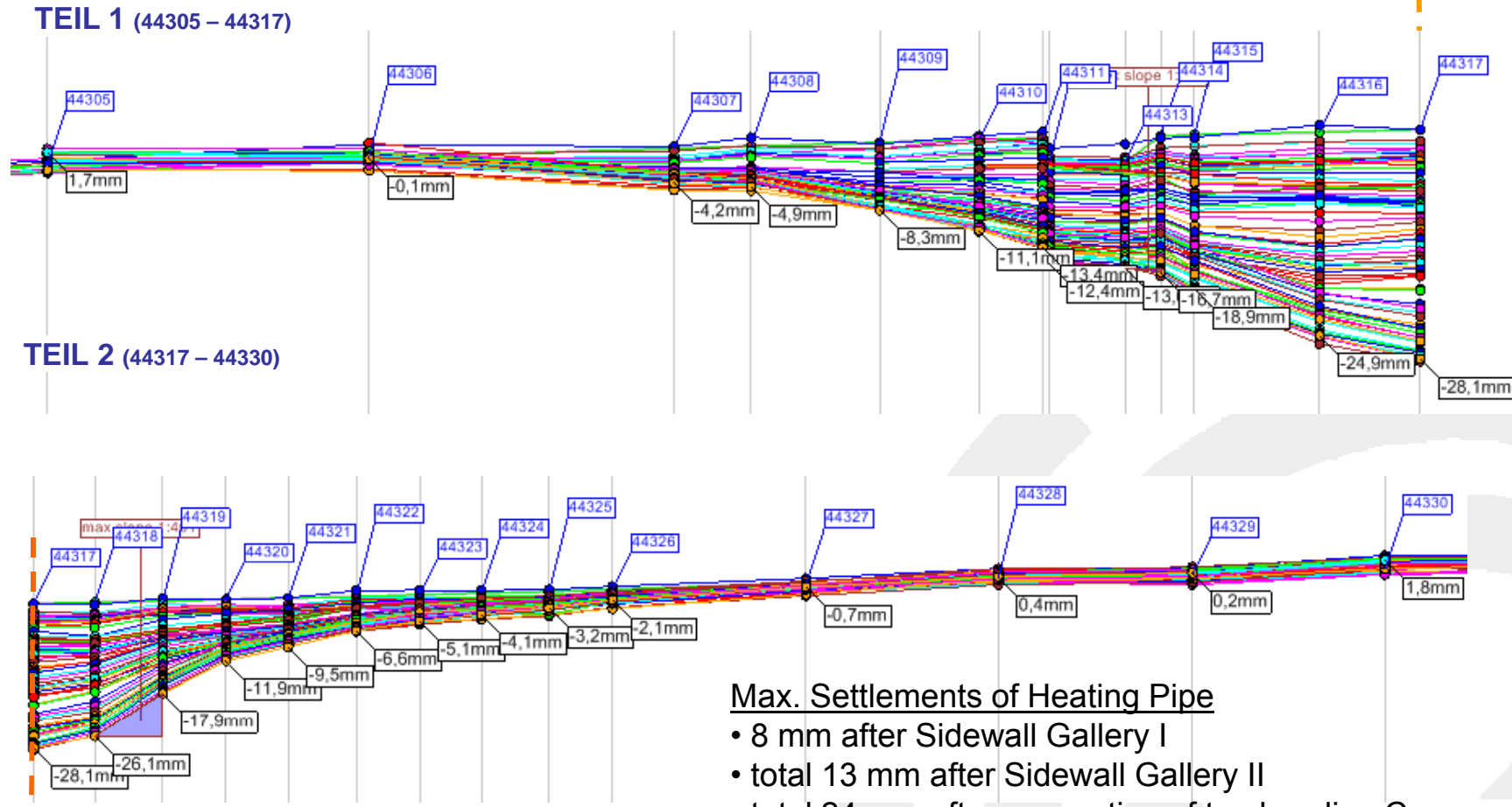
- FILL
- GRAVEL
- SAND/SILTY SAND
- SILT/CLAYEY SILT



CONSTRUCTION LOT LT44 – CROSSING OF HEATING PIPE



CONSTRUCTION LOT LT44 – CROSSING OF HEATING PIPE



Settlement Trough along Heating Pipe

- 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

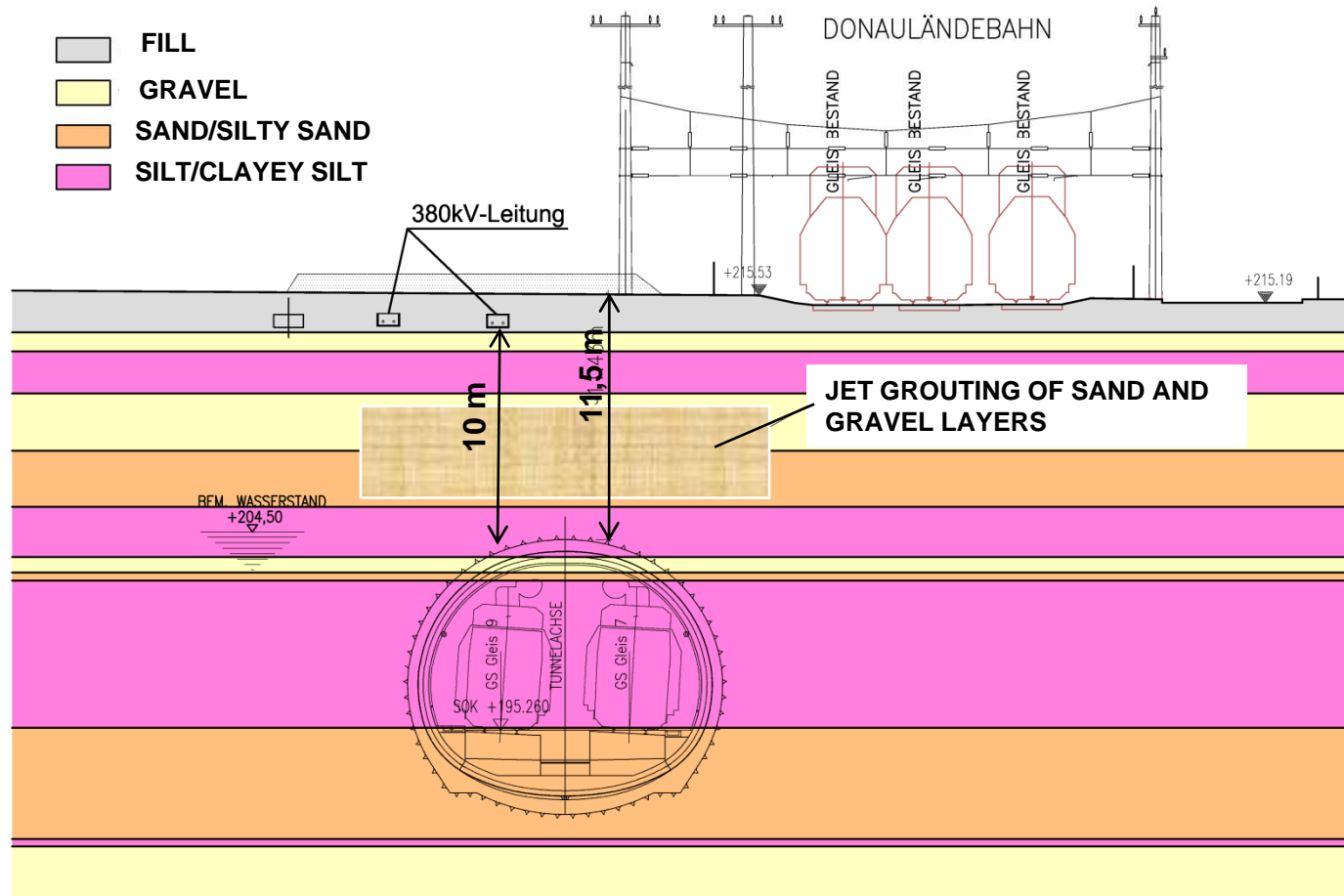
CONSTRUCTION LOT LT44 – CROSSING OF HEATING PIPE



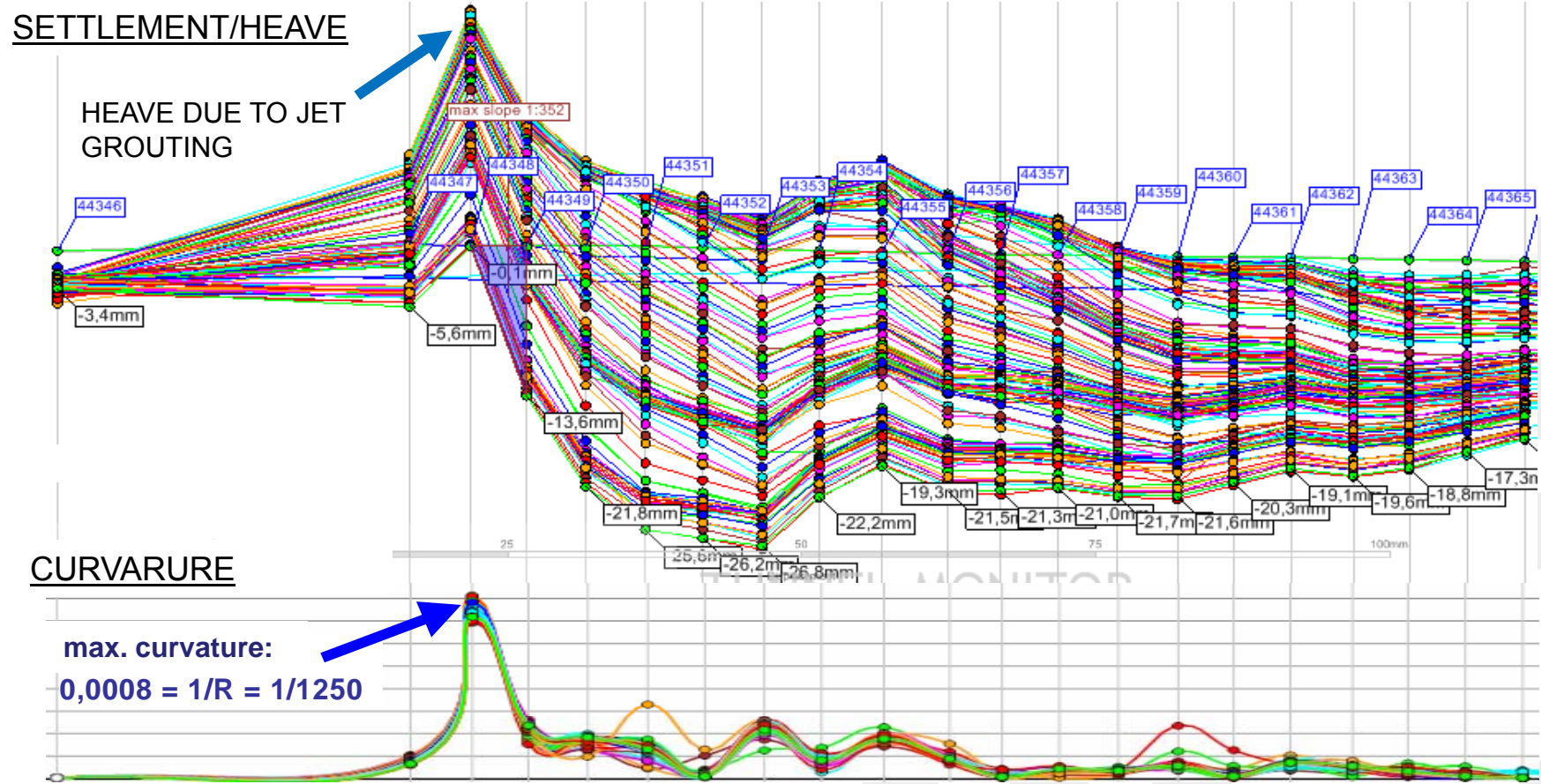
CONSTRUCTION LOT LT44 – CROSSING OF HEATING PIPE



CONSTRUCTION LOT LT44 – EXCAVATION UNDER HIGH VOLTAGE CABLES

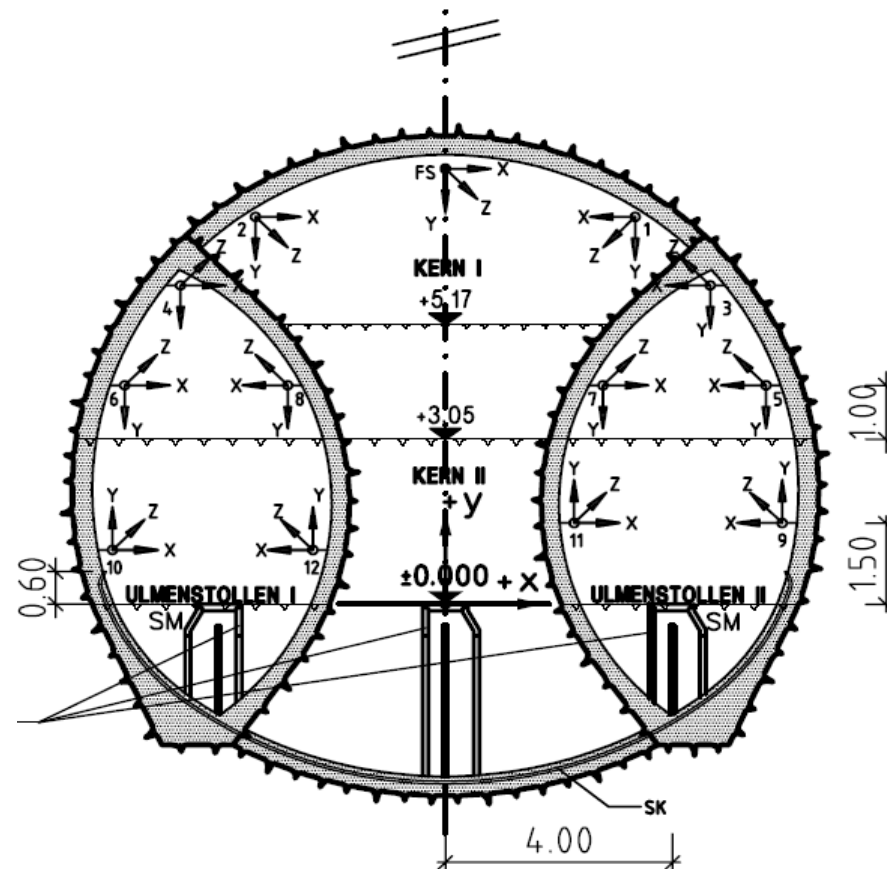


CONSTRUCTION LOT LT44 – EXCAVATION UNDER HIGH VOLTAGE CABLES



CONSTRUCTION LOT LT44 – GEOTECHNICAL MONITORING

- Spacing of monitoring sections max. 10 m
- Settlement monitoring in heating supply line
- Daily readings at least up to 30 m behind excavation face
- Sub-surface targets installed on power line



CONSTRUCTION LOT LT44 – INSITU CONCRETE LINING

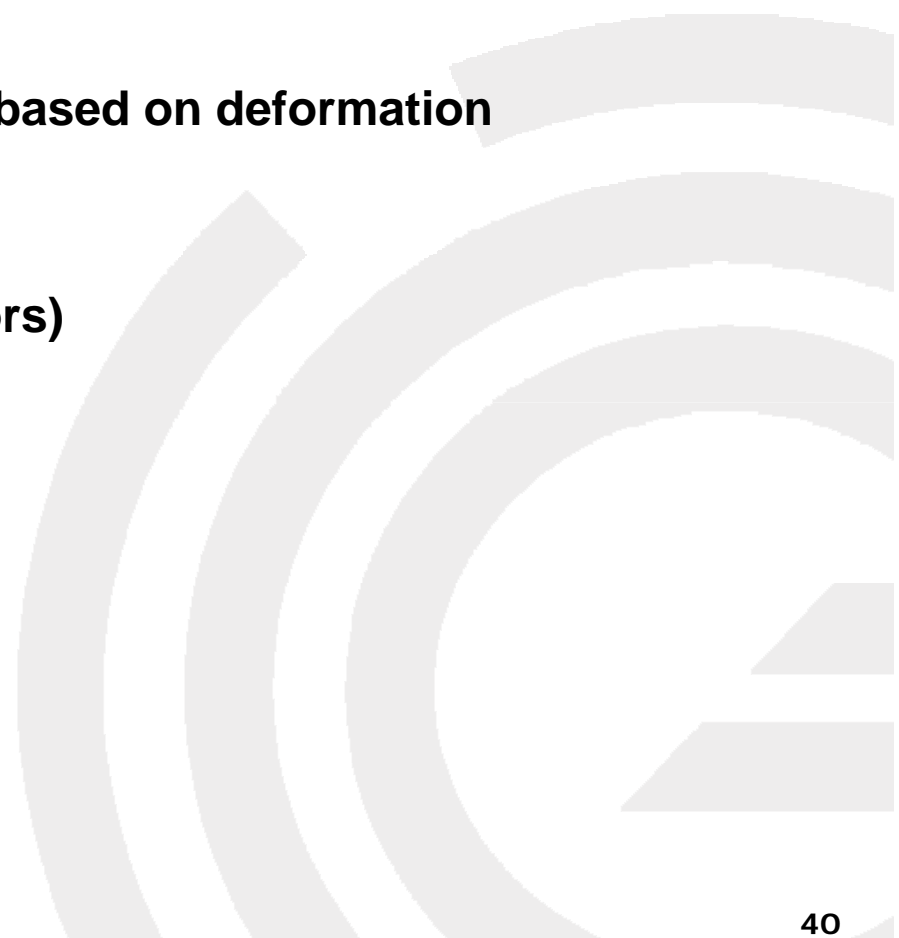




CONSTRUCTION LOT LT44 – GEOTECHNICAL MONITORING

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



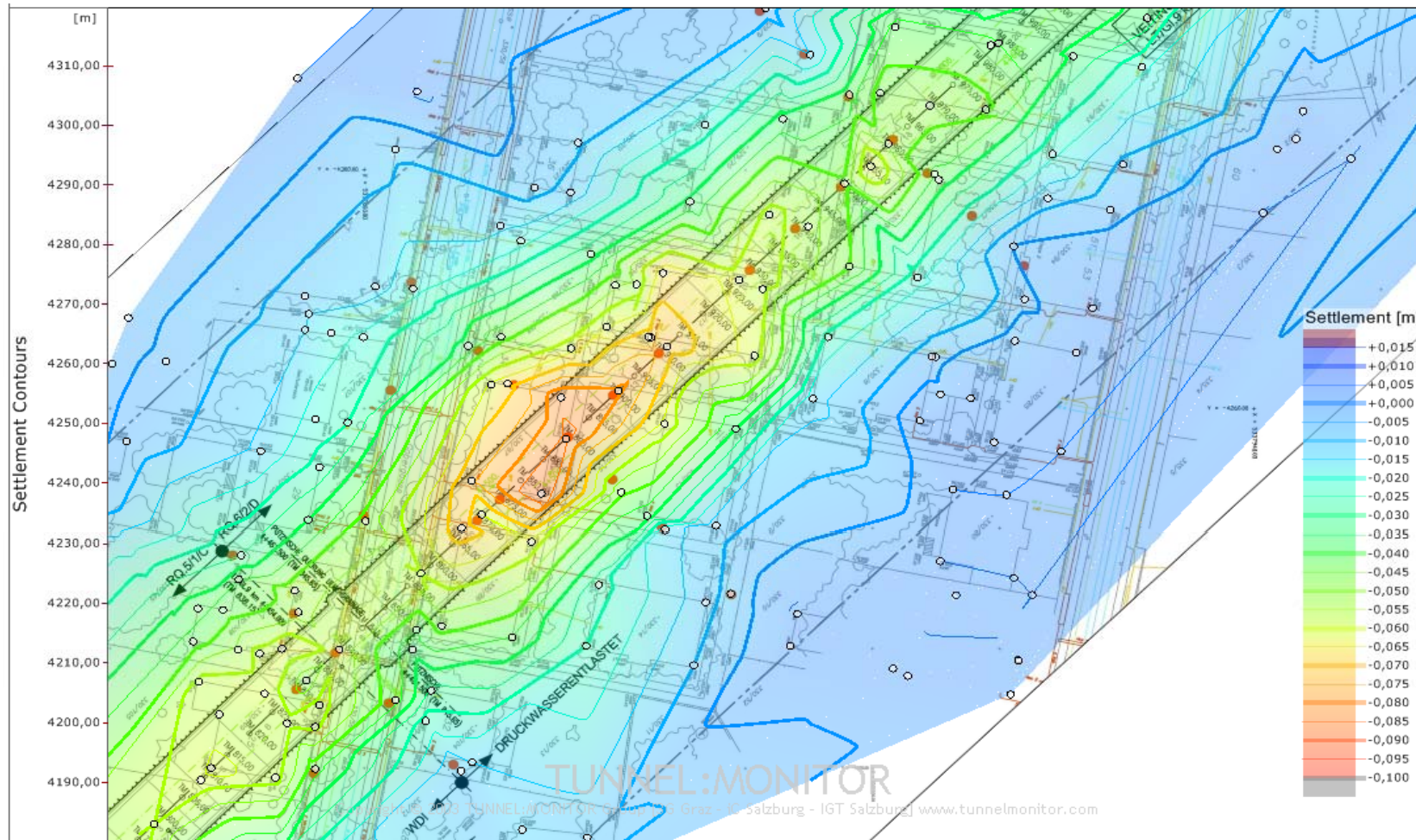
- + automatic monitoring from fixed monitoring stations (measurements every 15 min)
- + if monitoring results exceed defined alarm levels → alarm by SMS

Monitoring Stations



Monitoring Target

CONSTRUCTION LOT LT44 – GEOTECHNICAL MONITORING



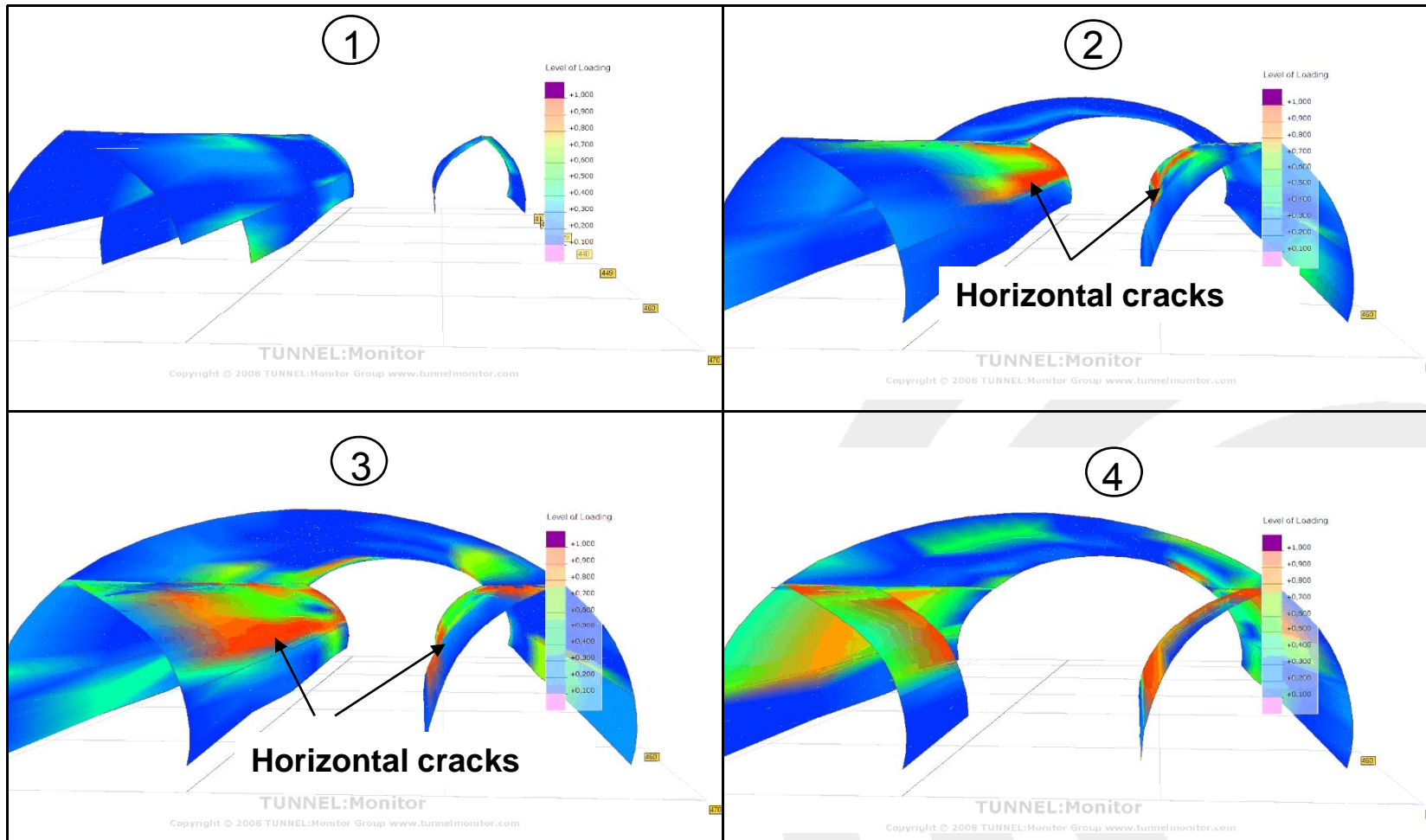
CONSTRUCTION LOT LT44 – GEOTECHNICAL MONITORING

MONITORING OF EXCAVATION FACE DISPLACEMENTS

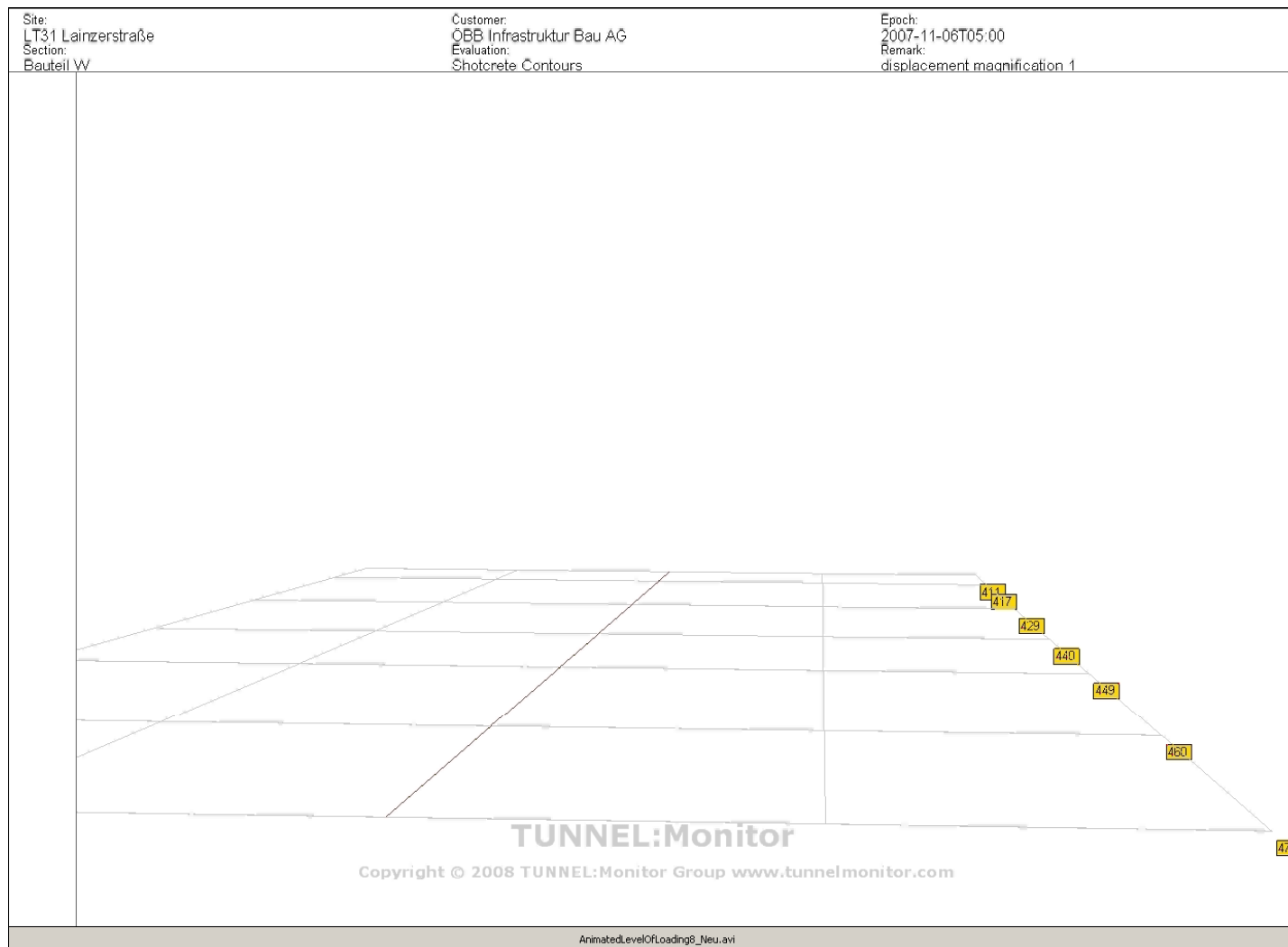


- + automatic monitoring of face displacements without reflectors
- + monitoring of 30 spots (measurements every 5 minutes).
- + if monitoring results exceed defined alarm levels
→ alarm by SMS

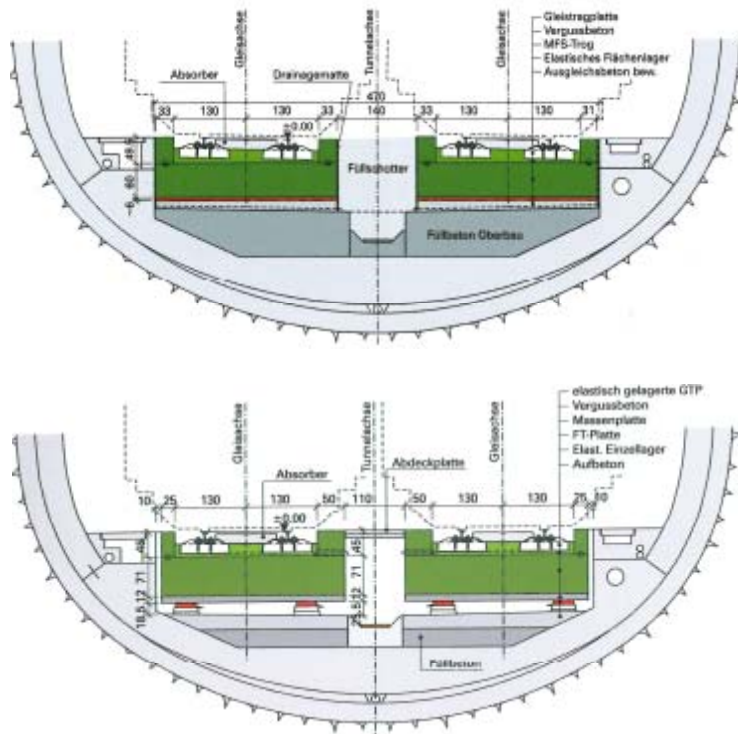
CONSTRUCTION LOT LT44 – GEOTECHNICAL MONITORING



CONSTRUCTION LOT LT44 – GEOTECHNICAL MONITORING



CONSTRUCTION LOT LT44 – TRACK SUPERSTRUCTURE



COMPLETION OF LAINZER TUNNEL IN 2012

