



## Basic Tunnel Parameters

- HW D2 and the 3,3 km long part of D2 Lamačská cesta - Staré Grunty in the northern part of the capitol of SR Bratislava
- Construction beginning 27.októbra 2003
- End of construction 8.2.2005 resp. 3.5. 2005
- In operation 24.6.2007
  
- 2 tubes, with HW parameters
  
- Western tube  
length - 1440 m, 1189 m (NATM)  
a 251 m (open pit)
  
- Eastern tube  
length - 1415 m, 1159 m (NATM)  
a 220 m (open pit)



## Tunnel Construction

- New Austrian Tunneling Method (NATM), both side
- 3 level (part) excavation
- primary ceiling
  - spread concrete up to 250 mm tickness, with one ore two steel laeyr
- secondary ceiling
  - monolithic steel-concrete with 300 - 350 mm tickness
- build in 10 m step (blocks)



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## Cunstruction Effects

- **Settling of the objects over the tunnel**
- **Stability disturbtion in geological surrounding**
- **Changes in hydrological conditions**
- **Tunnel operation can effect the objects over the tunnel also**
- **These changes and effects should be minimized in long term horizont**



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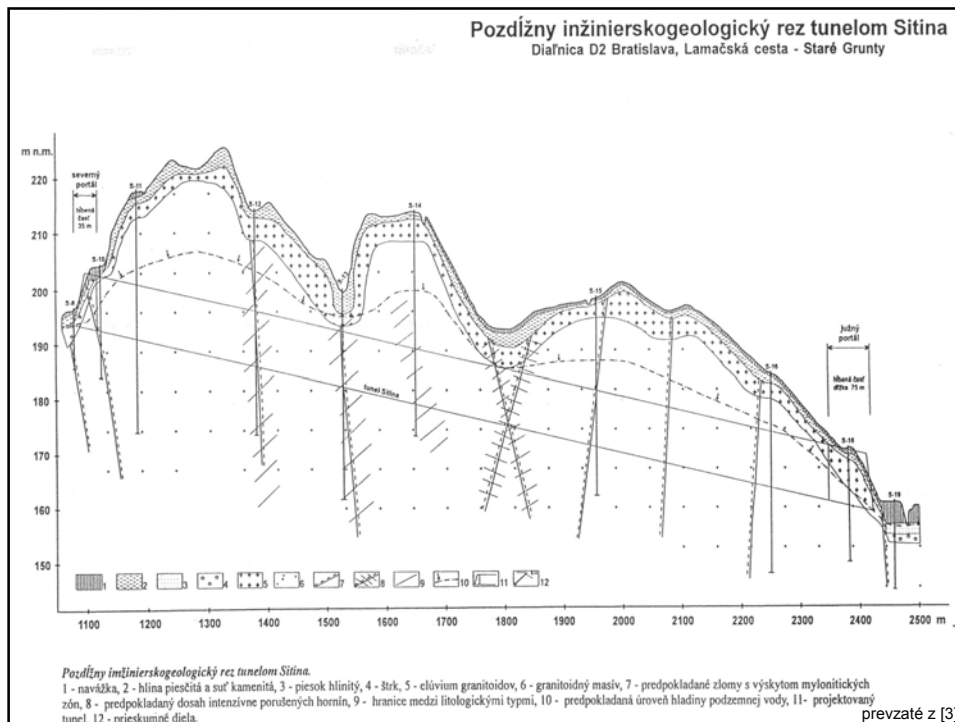
# Deformation Measurement Project

## STN 730405 Deformation measurement of civil engineering structures:

- aim and type of measurement,
- geological, geotechnic and hydrogeological conditions (geolog. investment),
- structure basement and loading,
- deformation values (expected),
- accuracy analysis (a priori) and required accuracy,
- measurement technology (method, instrumentation, etc.),
- control network, control points, measuring points
- maps, drawings, orthophoto products,
- time shedule of point building,
- tme shedule of measurements,
- data analysis, methodology, presentation,
- technical report timing, structure and form.

# Hydrogeological and geological investment

- Bratislava part of the Carpatian Massive (granits)
- Terrain - antropogen wast of 0,5 m tickness
- Geology:
  - crystalinicum
  - cvarter (wast)
  - neogen (sand and clay)
- Breack (shift) sones
- Underground water conditions - normal



$m_{rel} = 0.4 - 0.5mm$

## Expected deformation values

- expected relative deformation in control profiles up to 2.0 mm
- relative deformation two neighbouring control profiles up to 5.0 mm
- Required relative deformation determination 0.5 mm
- Required absolute deformation determination 2.0 mm



# Measuring methods, instruments

- Precise leveling
- 3D coordinate determination
- Free station and polygonometric measurement
- GNSS
- Combination of different methods



# Control Network

- Build before tunnel construction
- - underground (free station, polygonal)
- - outside (GNSS, trigonometric)
- local system, connected to the land systems (S-JTSK) and (BpV)
- southern portal - No.7000,2066,998  
7000A (designed)
- northern portal – No.857,1003  
1003A (designed)
- New high points in control network:  
VB1-VB4 (south portal)  
VB5-VB8 (north portal)  
VB9 (joint mark 1003A)



## Stabilization and protection of points

- Steel tubes, concrete
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- Upper part – centering device
- identification – table with point No.
- New high points – in the base structures of large traffic sings
- Spot markers
- identification

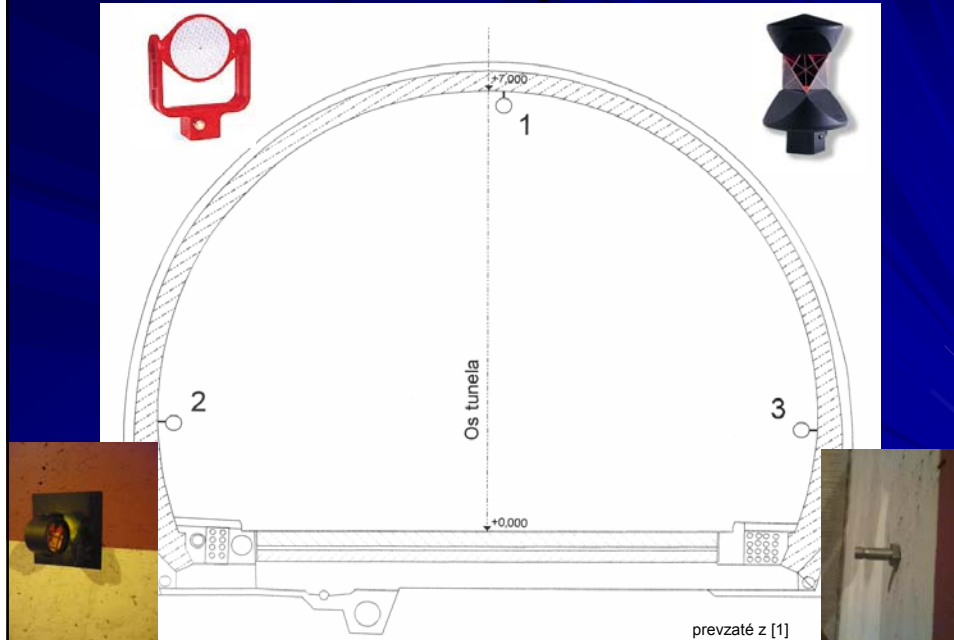


## Control points

- Position determined according the geoloigac investment and tunnel design
- 3 points in each profile
  - 2 points in both side (max. 1m over the road lev.)
  - 1 point in the top of the tunnel arc
- Profile identification
- Next points – 2 new levelling points in each emergency exit tube
- stabilization using rustless steel structure (amchor),
- 3D position repeating with accuracy up to 0.2 mm,
- Protection between two measurement.



## Control points



## Determined values

### ■ Determined values :

- a) control point parameters outside the tunnel
- b) vertical deformation of the control profile points and points in the emergency exit tubes
- c) absolute and relative 3D deformation of profile points

including accuracy parameters....

## Time shedule

- Not possible during the operation
- One measurement in 6 months, in term of 3 years
- Measuring time – during operation breaks, max. 6 hours
- Minimisation of effects other activities during the breaks



## Data processing and analysis

- Aim => parameters of measuring points (including accuracy characteristics)
- LMNQUE method (2. linear model, 3. linear model)
- Testing of results – confidence level  $\alpha=0.05$
- Connection to the official land networks



# Conclusion

- New points outside the tunnel needed - 1003 A a 7000A, VB1-VB9
- Special stabilization of measuring points tunnel inside – possibility of the position repeatability up to 0.2 mm
- 6 month interval in term of 3 years - to ensure the safety tunnel operation and traffic conditions
- Main control – David Coulthard (McLaren-Mercedes)



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