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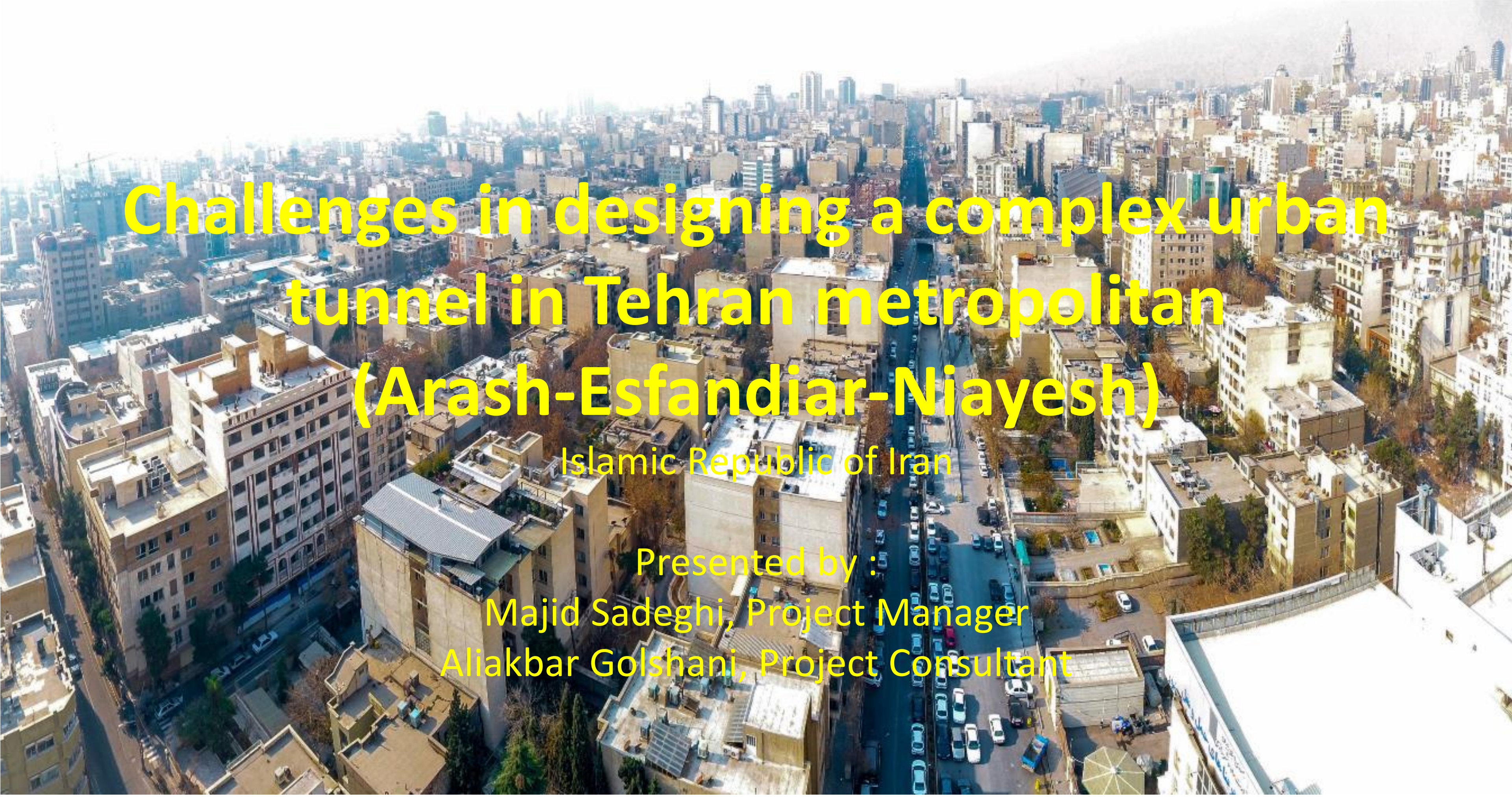
TECHNICAL PROJECT INNOVATION - OF THE YEAR -



Challenges in designing a complex urban tunnel in Tehran metropolitan (Arash-Esfandiar-Niayesh)

Islamic Republic of Iran

Presented by :
Majid Sadeghi, Project Manager
Aliakbar Golshani, Project Consultant

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TECHNICAL PROJECT INNOVATION - OF THE YEAR -

Owner

- Engineering and Development Organization of the City of Tehran

Consultants

- POR Consulting Engineers
- CVR Consulting Engineers

Contractor

- Hera Co.

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TECHNICAL PROJECT INNOVATION - OF THE YEAR -

Tehran

- Population: about 14 millions people
- The second- largest metropolitan area in the Middle east.

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TECHNICAL PROJECT INNOVATION - OF THE YEAR -

- To increase Traffic capacity from east to west in North of Tehran (Due to locating number of main north to east routes in this area)

Arash-Esfandiar-Niayesh Tunnel

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TECHNICAL PROJECT INNOVATION - OF THE YEAR -

Project specifications:

- Tunnel length: 1451m
- Ramp length: 1068m
- Overburden: 3 to 14m
- Excavation width: 6.90 to 20m

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TECHNICAL PROJECT INNOVATION - OF THE YEAR -

Project specifications:

- Underneath Residential Areas
- Under passing number of vital arteries
- Three emergency exits
- Multiple cross sections
- One Bifurcation (1.5 Lane+2 Lane)
- One Electrical substation tunnel

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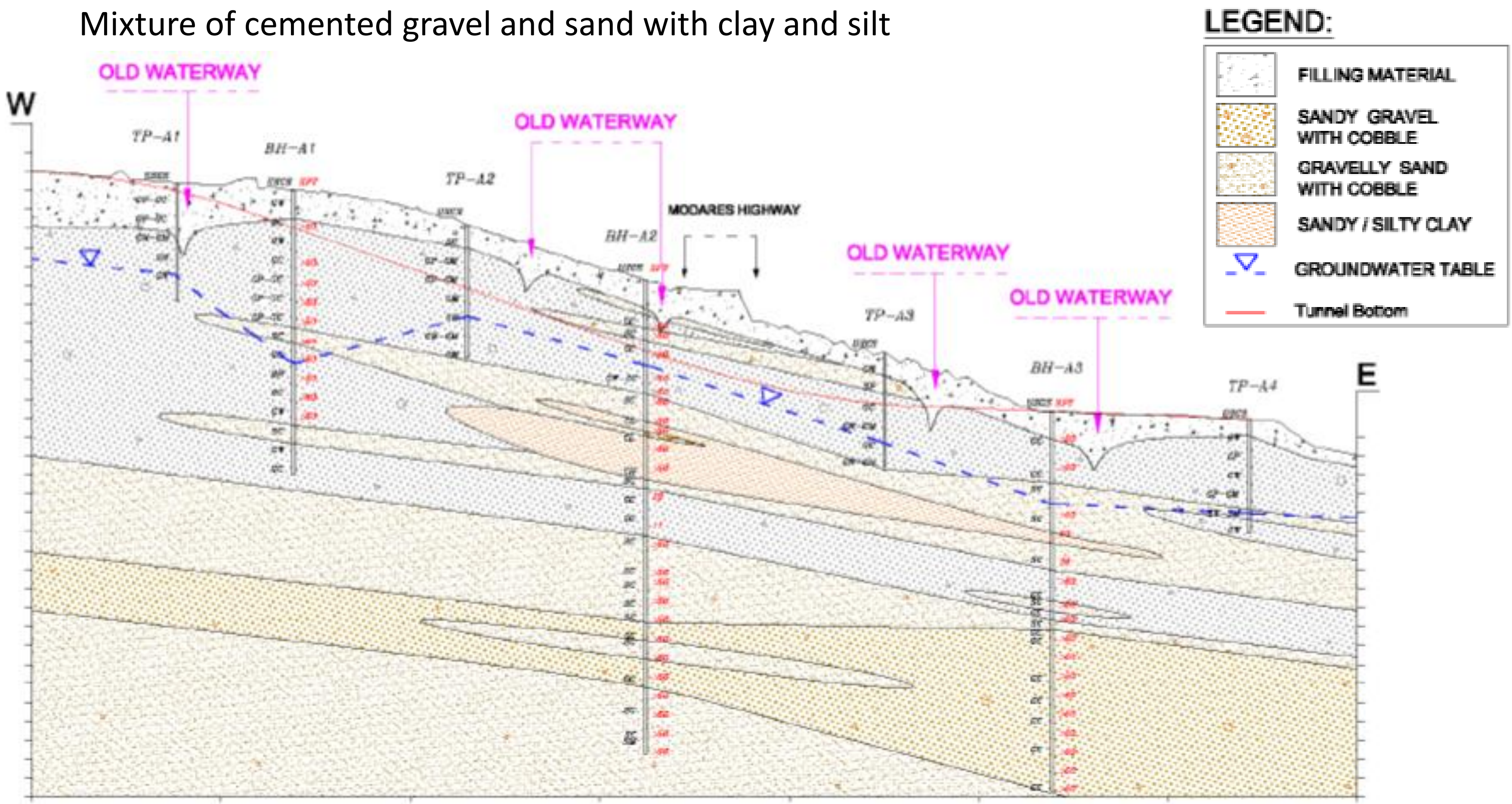
TECHNICAL PROJECT INNOVATION - OF THE YEAR -

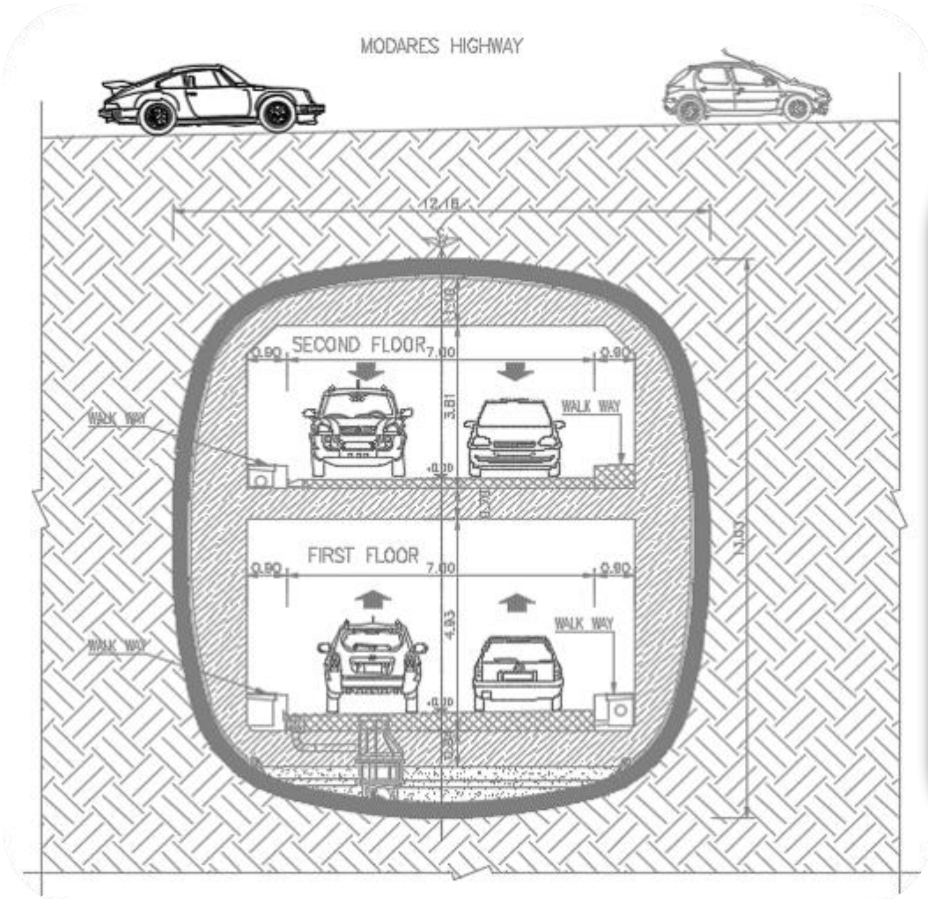
- **Geological long section**

Mixture of cemented gravel and sand with clay and silt



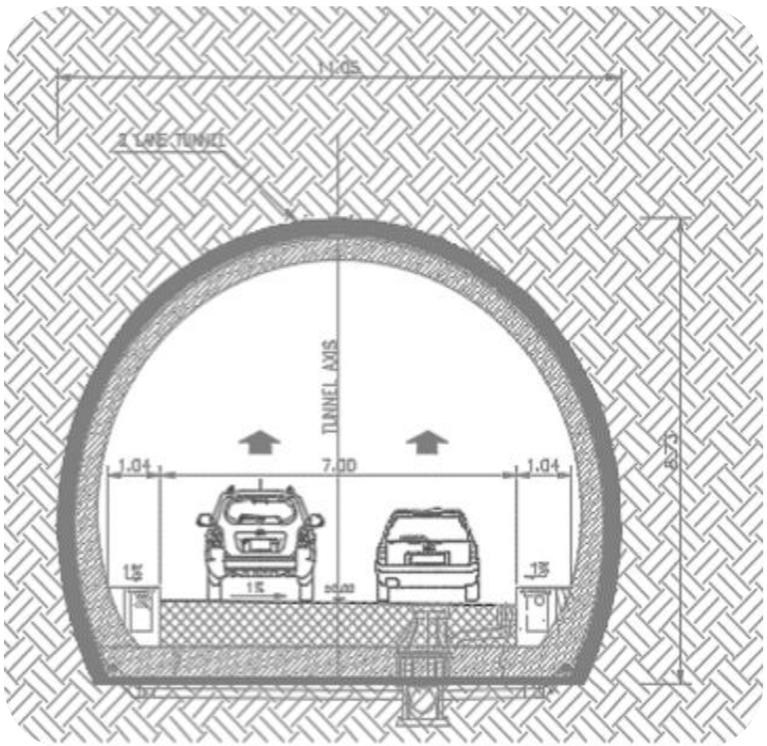
- **Multiple Cross sections:**

1- Modares Tunnel (Two-story tunnel) Height: 13m Width: 12.2m



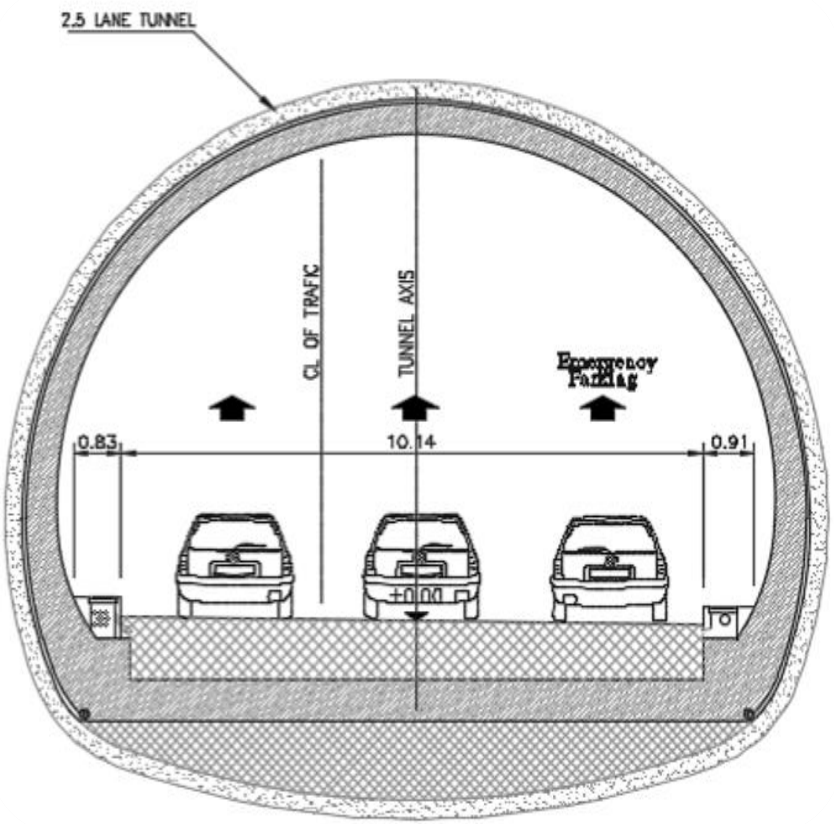
- **Multiple Cross sections:**

2- Two traffic lane Tunnel Height: 8.7m Width: 11m



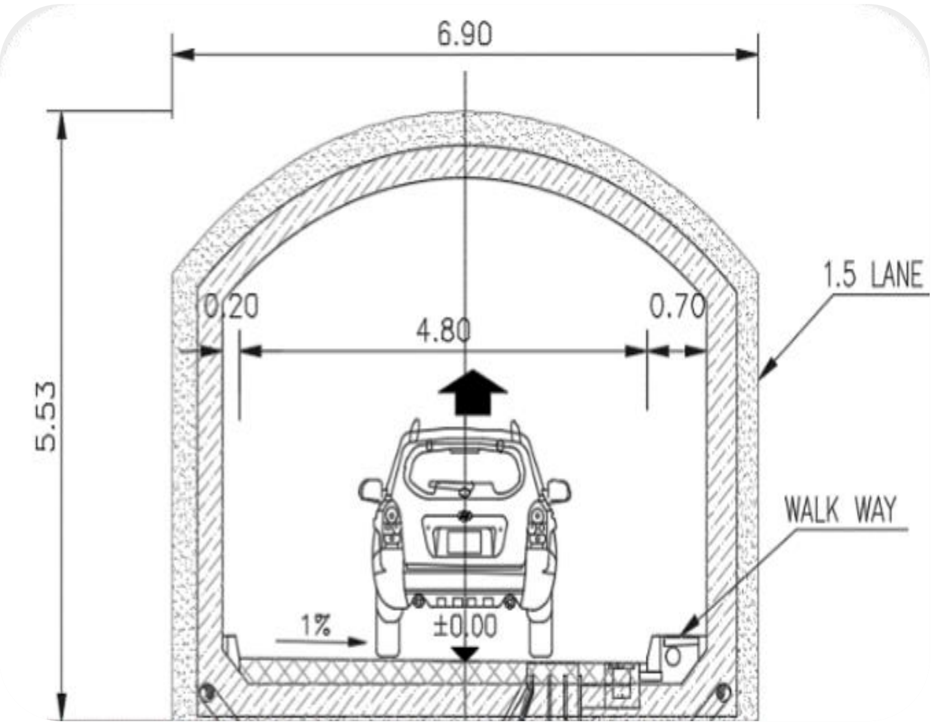
- **Multiple Cross sections:**

3- 2.5 traffic lane Tunnel Height: 11.9m Width: 14.4m



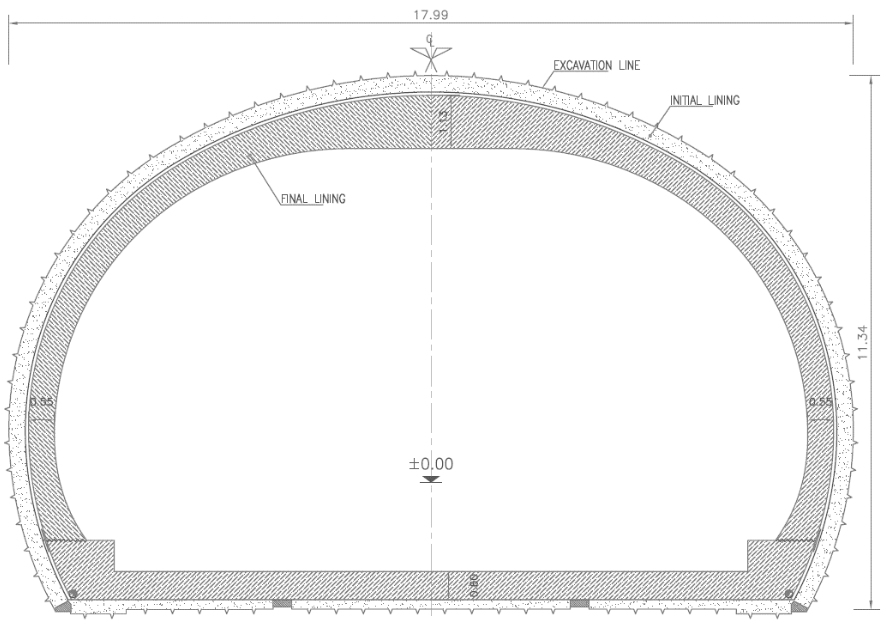
- **Multiple Cross sections:**

4- 1.5 traffic lane Tunnel Height: 5.5m Width: 6.9m



- **Multiple Cross sections:**

5- Three traffic lane Tunnel Height: 11.3m Width: 18m



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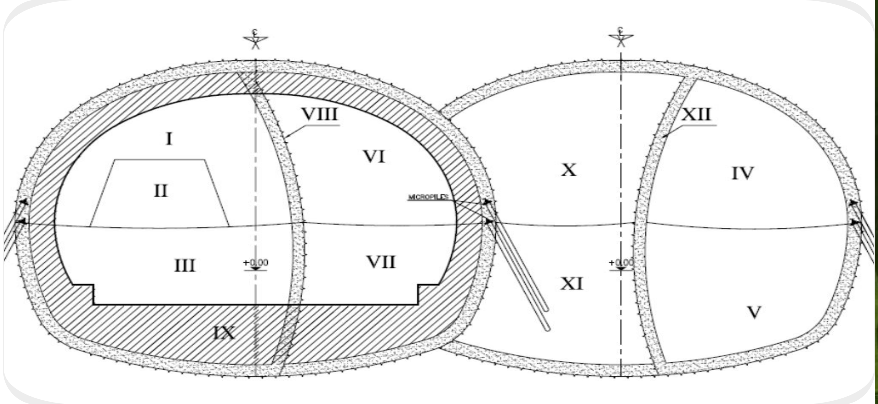
TECHNICAL PROJECT INNOVATION - OF THE YEAR -

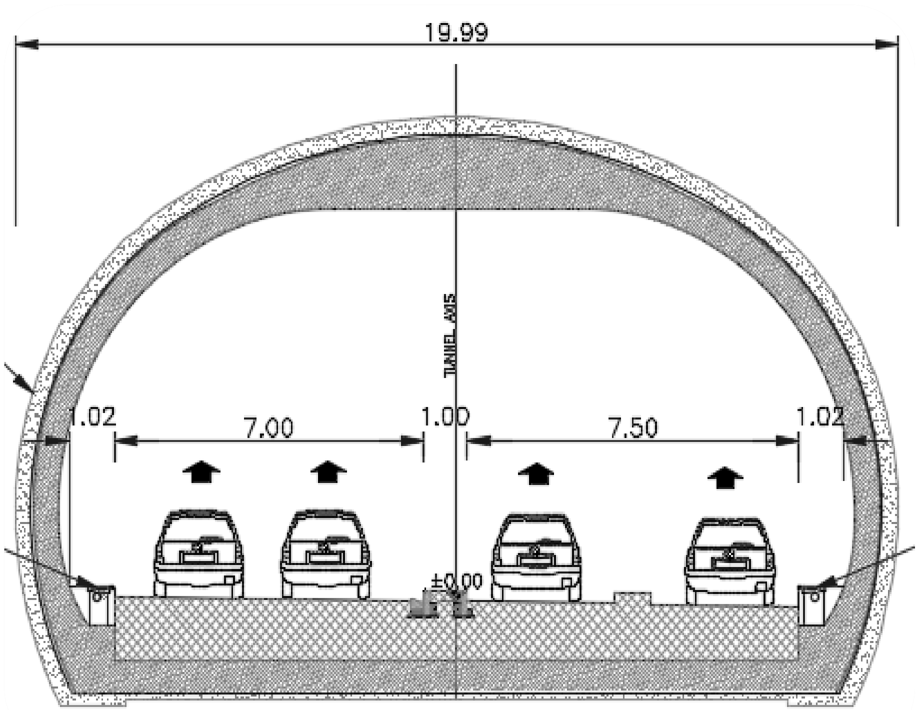
- **Multiple Cross sections:**

6- Valiasr Tunnel (Twin tunnel) Height: 8m Width: 18.3m



- **Multiple Cross sections:**

7- Enlarged 3.5 traffic lane Tunnel   Height: 11.6m   Width: 20m



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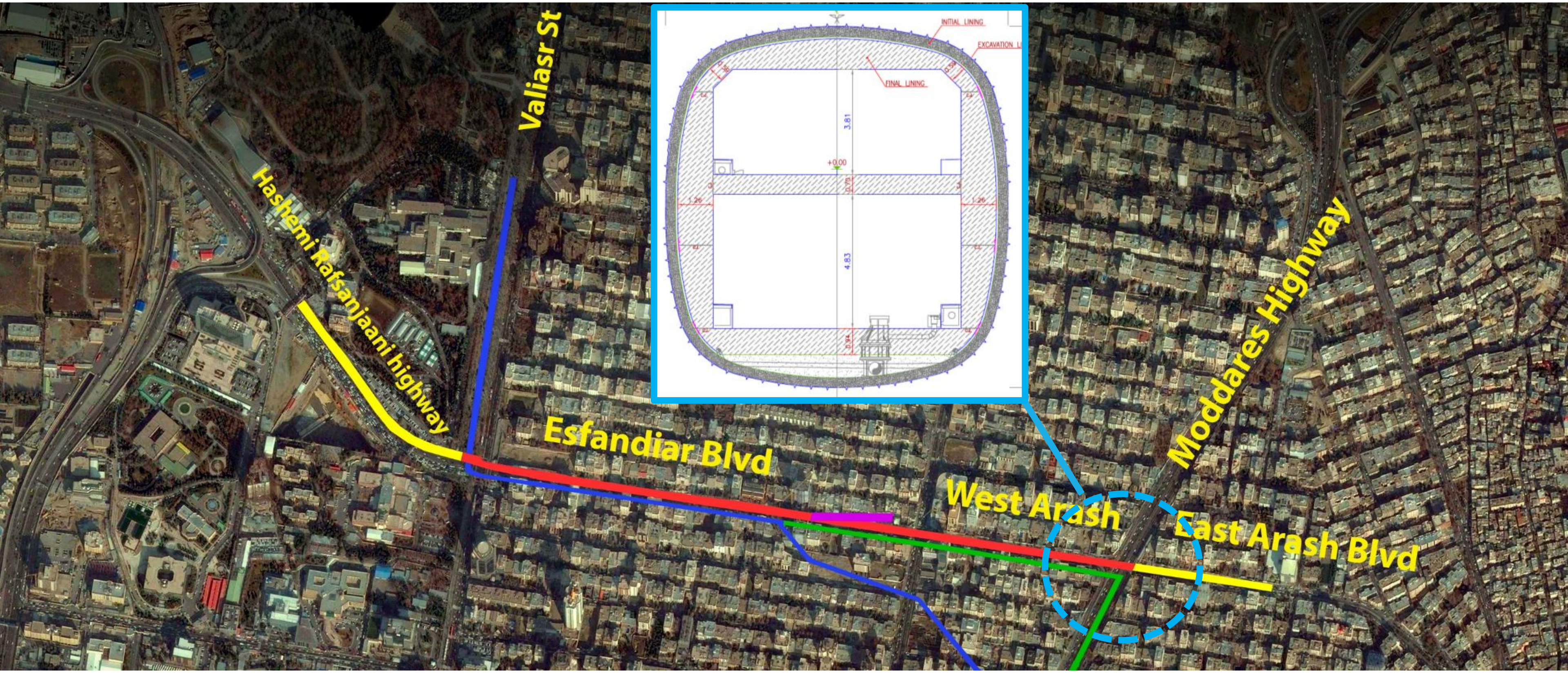
TECHNICAL PROJECT INNOVATION - OF THE YEAR -

Modares Tunnel:

- Two-story tunnel with the length of 52.3 m, 12.8m width and 13m height and the overburden of 3 m
- Under passing Modares Highway
- Ground settlement restricted to allowable limit



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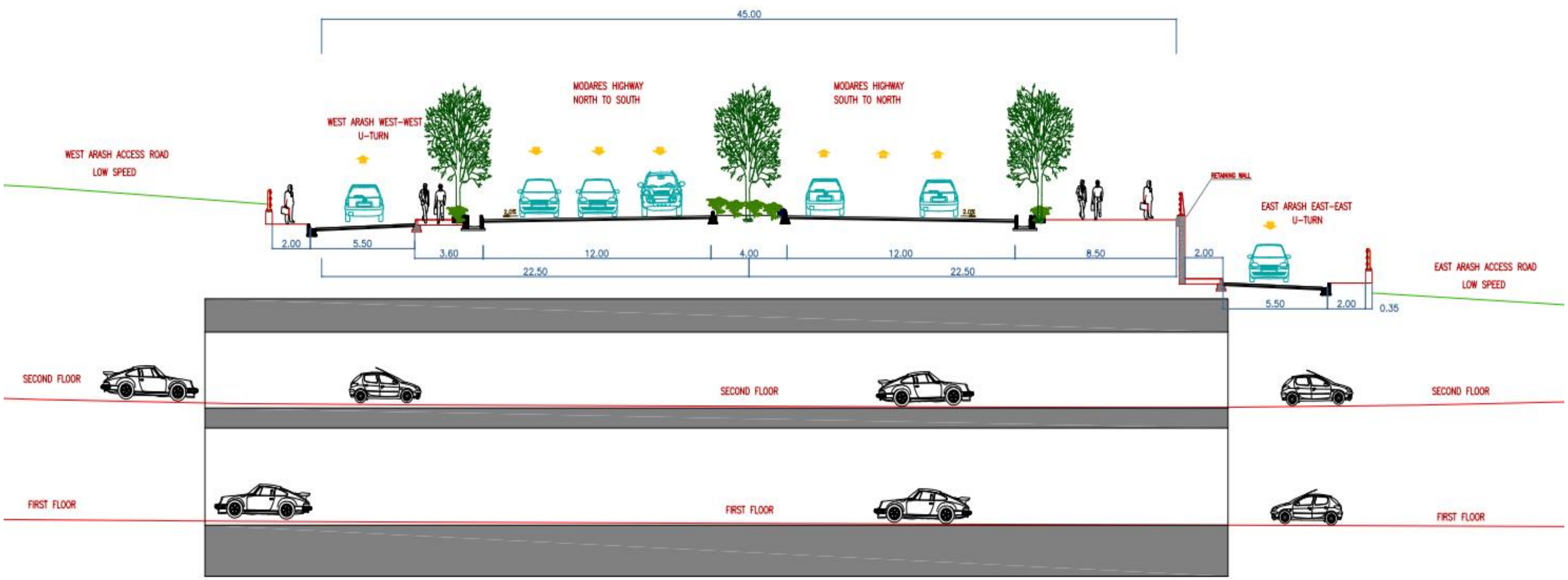
- **Modares Tunnel:** a rather square section (two-story section)

Combination of different supporting approach including NATM, Soil Improvement (fore-poling, micropile and nailing) simultaneously in order to reach a safe construction



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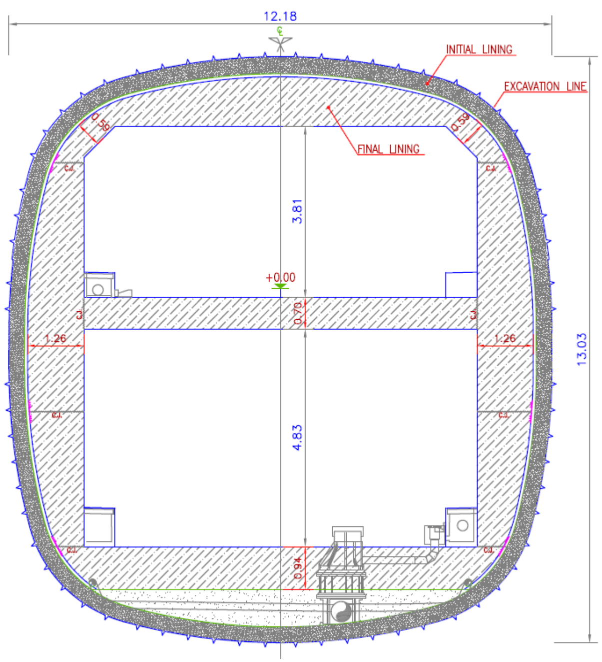
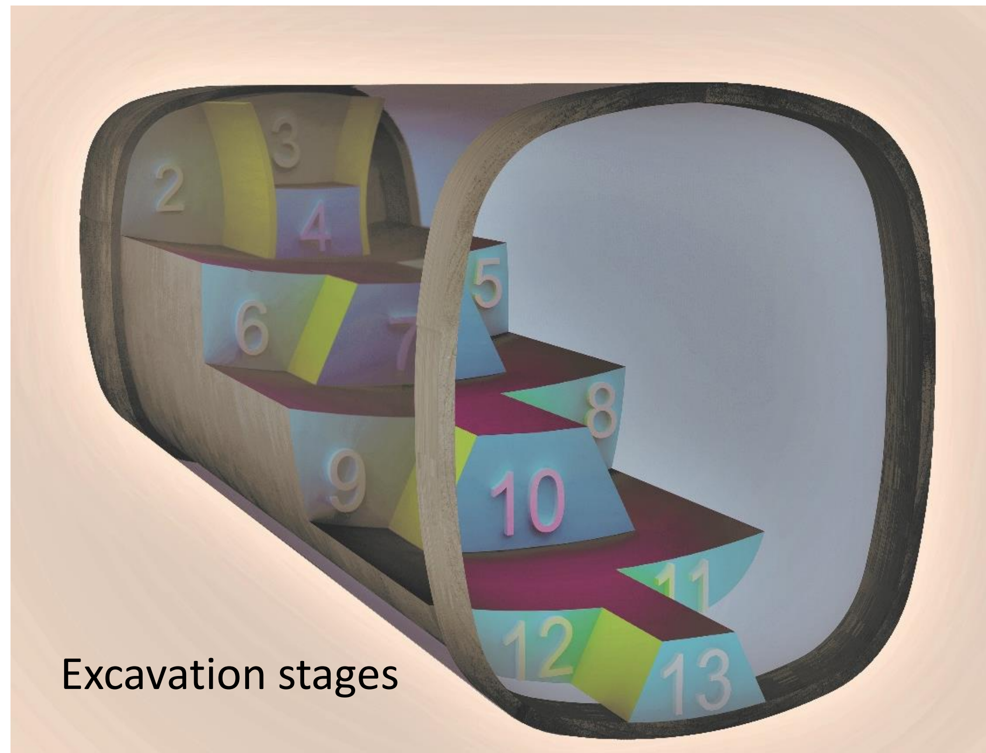
TECHNICAL PROJECT INNOVATION - OF THE YEAR -

- **Modares Tunnel:** a rather square section (two-story section)

Combination of different supporting approach including NATM, Soil Improvement (fore-poling, micropile and nailing) simultaneously in order to reach a safe construction





Excavation stages

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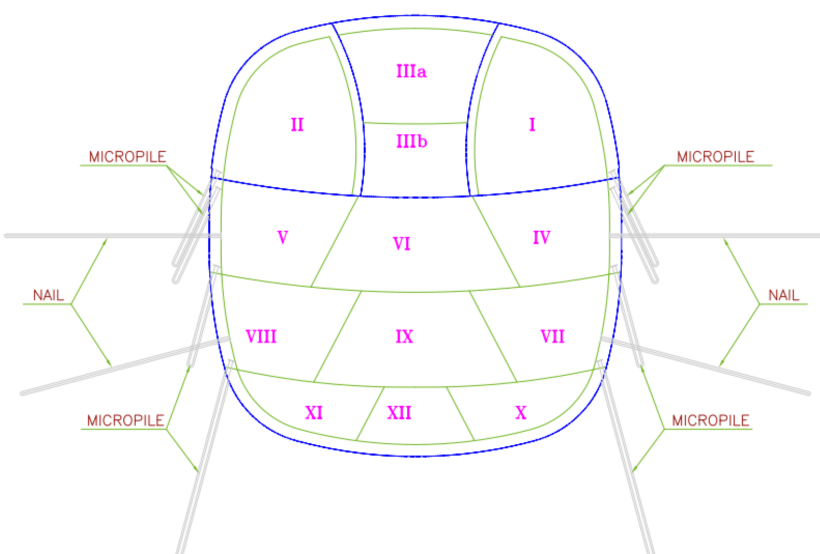
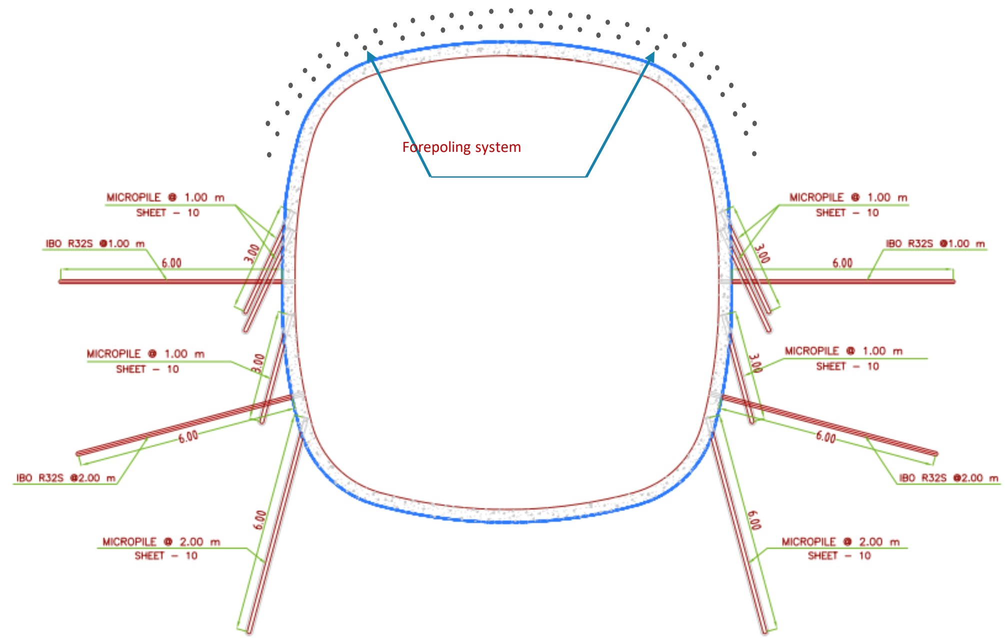
TECHNICAL PROJECT INNOVATION - OF THE YEAR -

- **Modares Tunnel**



Construction stages of modares tunnel



Initial lining supporting elements specifications

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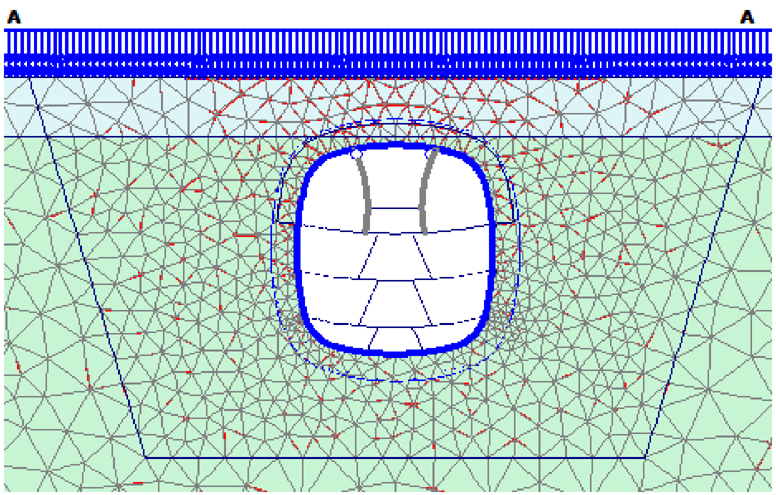
- **Modares Tunnel:**

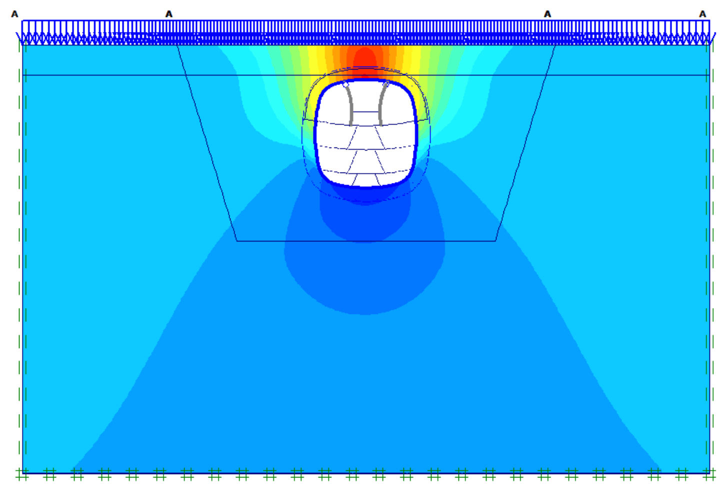
Five numerical models with different extra supporting system were simulated for Modares Tunnel excavation process;

Model NO.	Extra Supporting Systems		
	Fore pole	Micropile	nail
1	-	-	-
2	✓	-	-
3	-	✓	-
4	-	-	✓
5	✓	✓	✓

Modares Tunnel

- **Model No. 1 (NATM method, no extra supporting system)**





Vertical displacements (Uy)

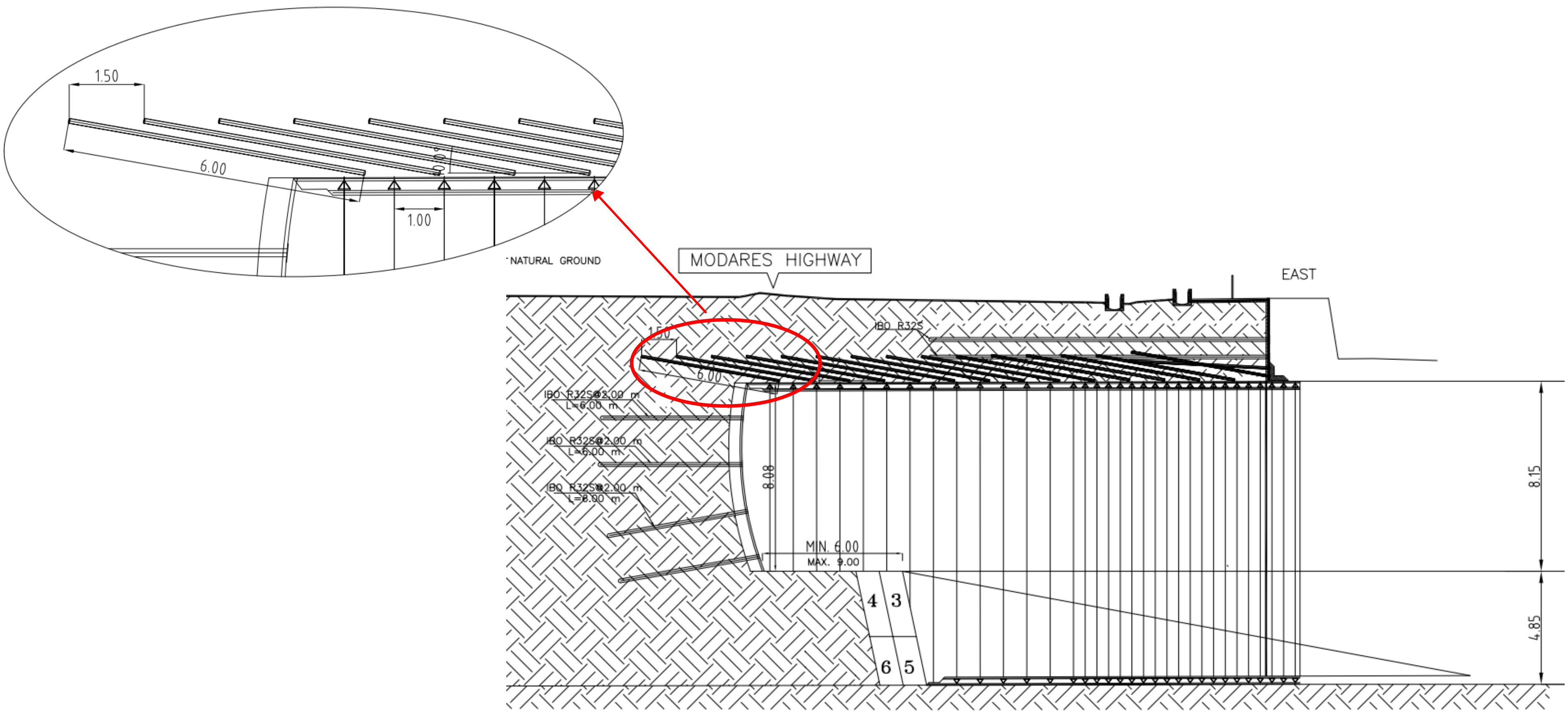
Extreme Uy -56.42×10^{-3} m

Allowable surface settlement (mm)	**25.4**
Maximum total vertical displacement (mm)	56.42
Maximum surface settlement (mm)	51.35

→ More than allowable settlement

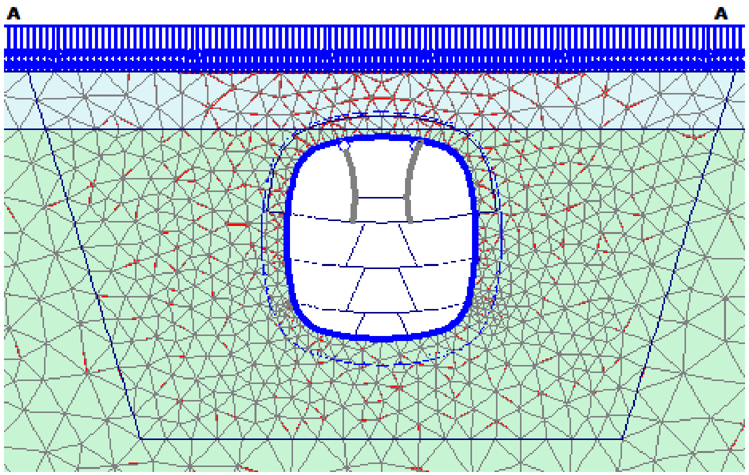
Modares Tunnel

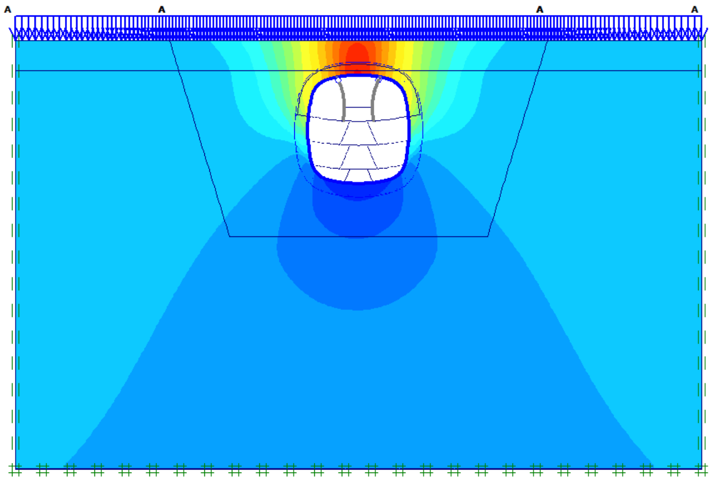
- **Model No. 2 (NATM method with Fore poles)**
  60 fore-poles in two rows with length of 6.00m



Modares Tunnel

- **Model No. 2 (NATM method with Fore poles)**





Vertical displacements (Uy)
Extreme Uy -56.42*10 $^{-3}$ m

Allowable surface settlement (mm)	25.4
Maximum total vertical displacement (mm)	56.42
Maximum surface settlement (mm)	51.35

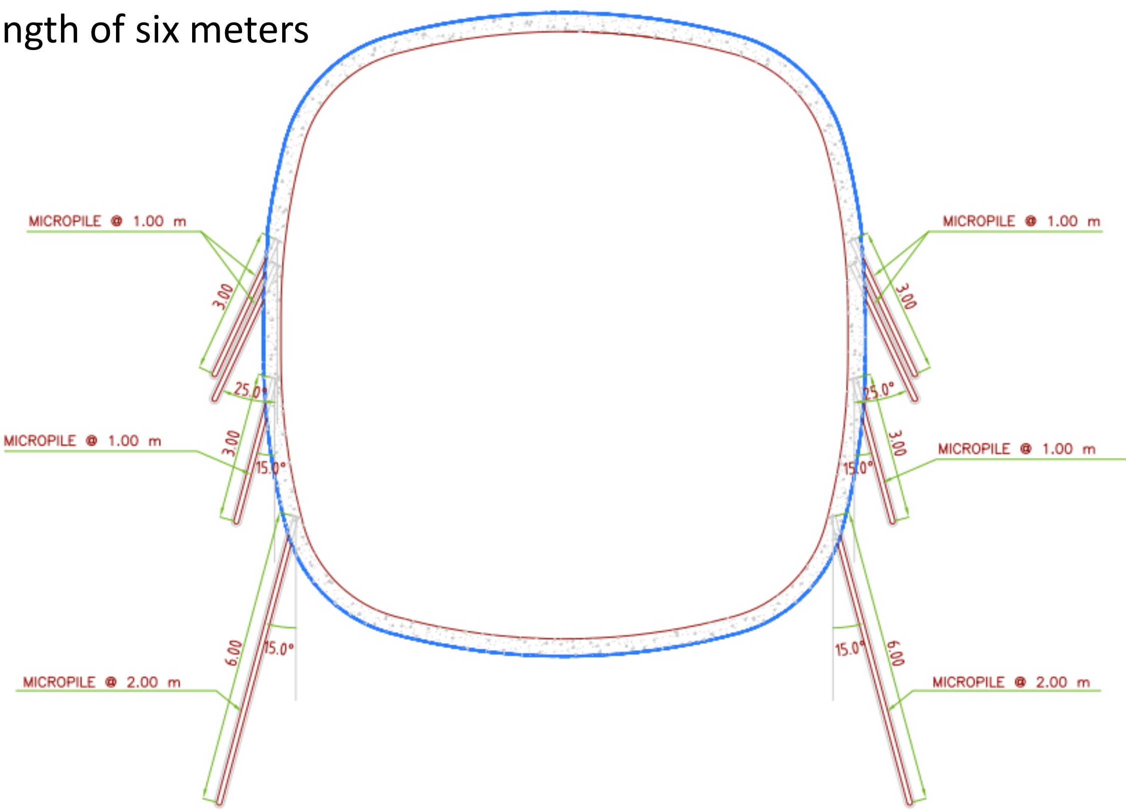
→ More than allowable settlement

Modares Tunnel

- **Model No. 3 (NATM method with Micro-piles)**

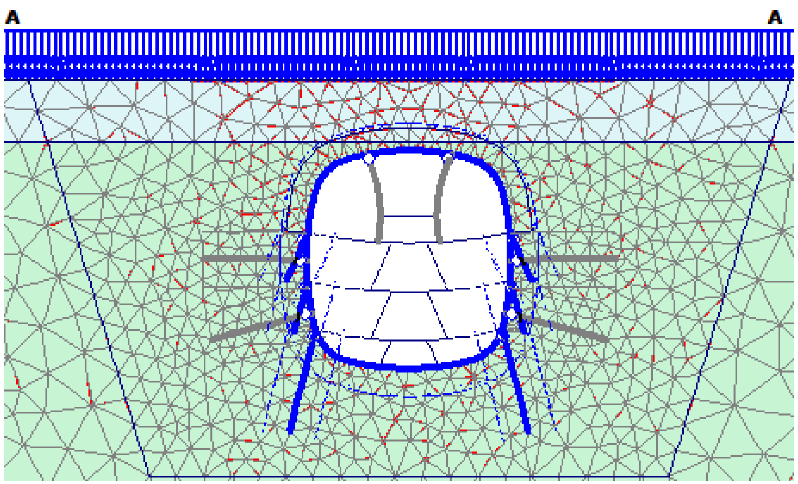
Six micropiles Ø32 with vertical deviation 15°

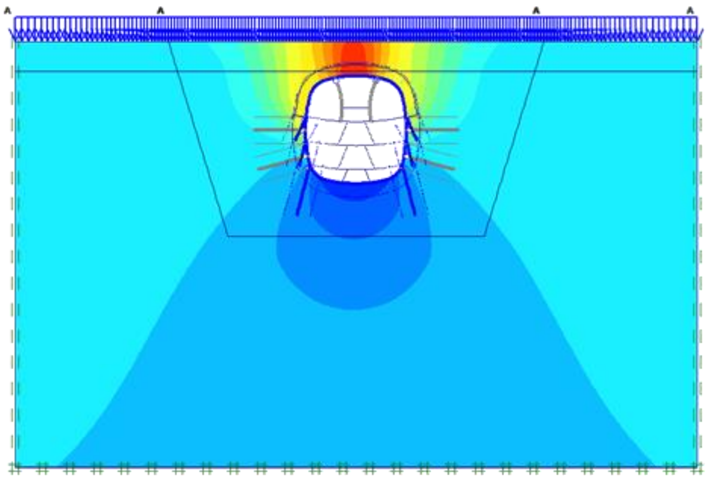
- Four micro-piles with the length of three meters
- Two micro-piles with the length of six meters



Modares Tunnel

- **Model No. 3 (NATM method with Micro-piles)**





Vertical displacements (Uy)
Extreme Uy -44.05*10^-3 m

Allowable surface settlement (mm)	25.4
Maximum total vertical displacement (mm)	44.05
Maximum surface settlement (mm)	40.41

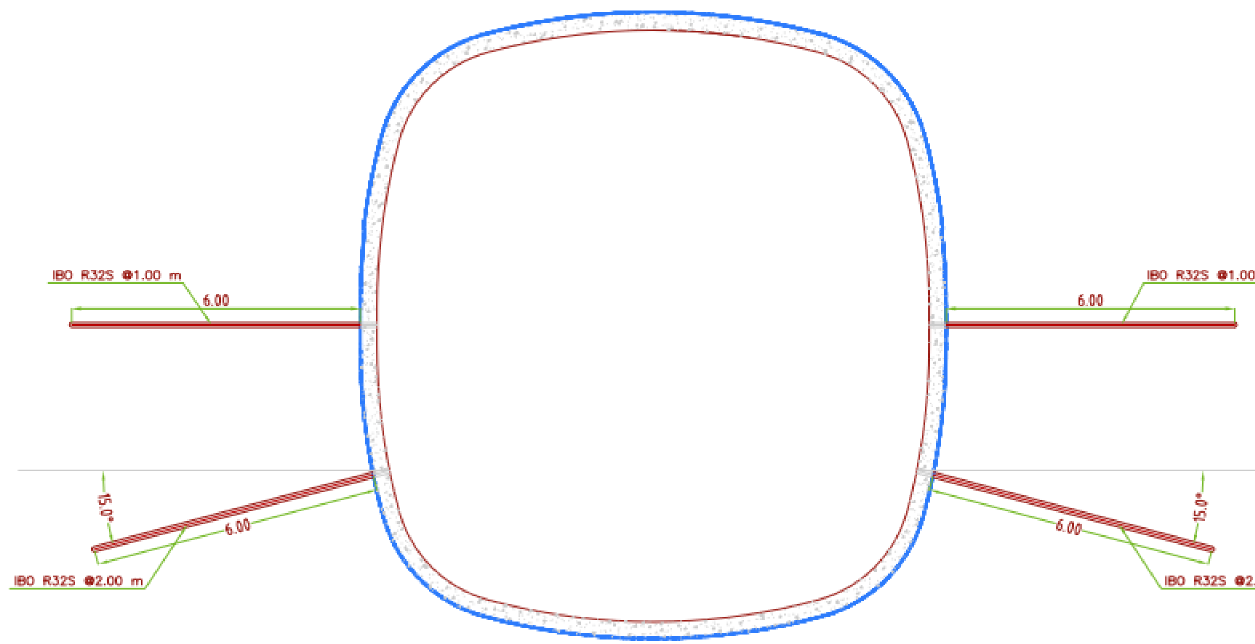
→ More than allowable settlement

Modares Tunnel

- **Model No. 4 (NATM method with Nails)**

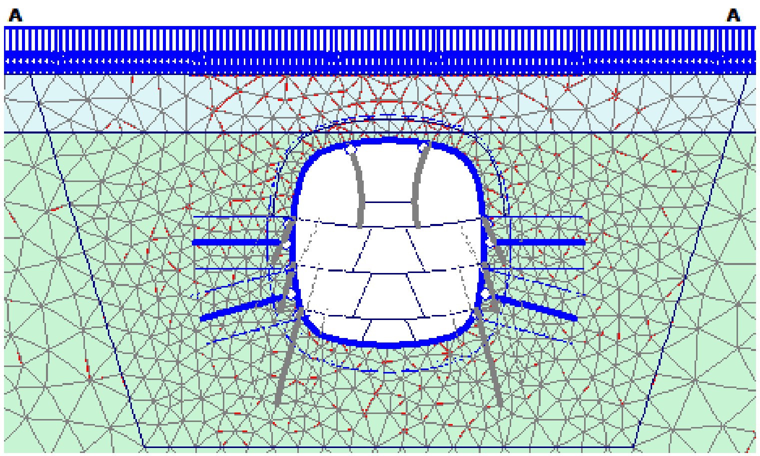
Four nails IBO R32S with the length of 6 meters

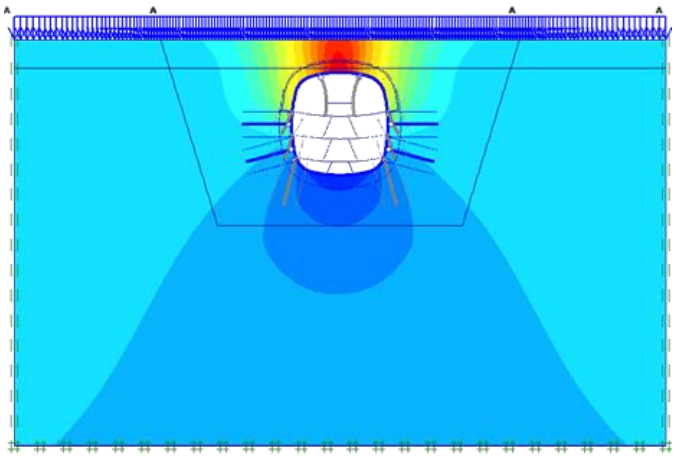
- Two horizontal nails
- Two nails with horizontal deviation of 15°



Modares Tunnel

- **Model No. 4 (NATM method with Nails)**





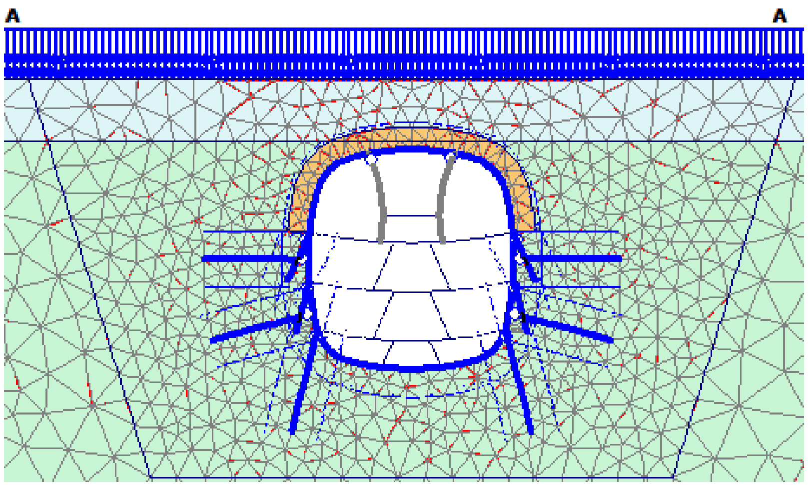
Vertical displacements (Uy)
Extreme Uy -50.29×10^{-3} m

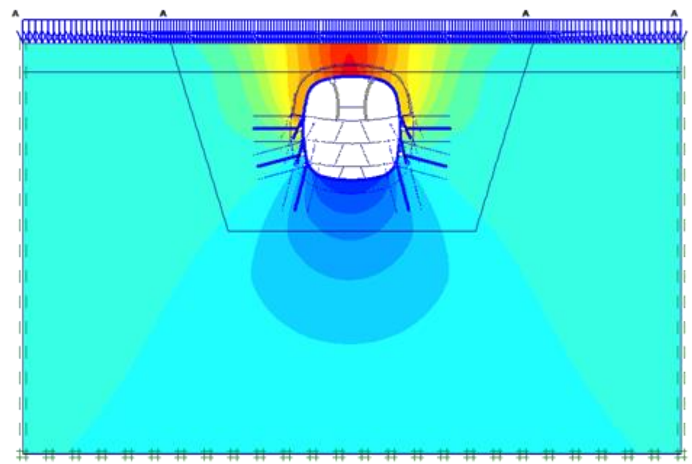
Allowable surface settlement (mm)	25.4
Maximum total vertical displacement (mm)	50.29
Maximum surface settlement (mm)	45.79

→ More than allowable settlement

Modares Tunnel

- **Model No. 5 (NATM method with Fore-poling, Micro-piles and Nails)**





Vertical displacements (Uy)
Extreme Uy -29.16*10^{-3} m

Allowable surface settlement (mm)	25.4
Maximum Total vertical displacement (mm)	29.16
Maximum surface settlement (mm)	24.90

→ Less than allowable settlement

Therefore for construction of Modares tunnel (with rather square cross section), NATM method with Fore-poling, Micro-piles and Nails were used.

Modares Tunnel

Ground settlement & Maximum bending moment of the models

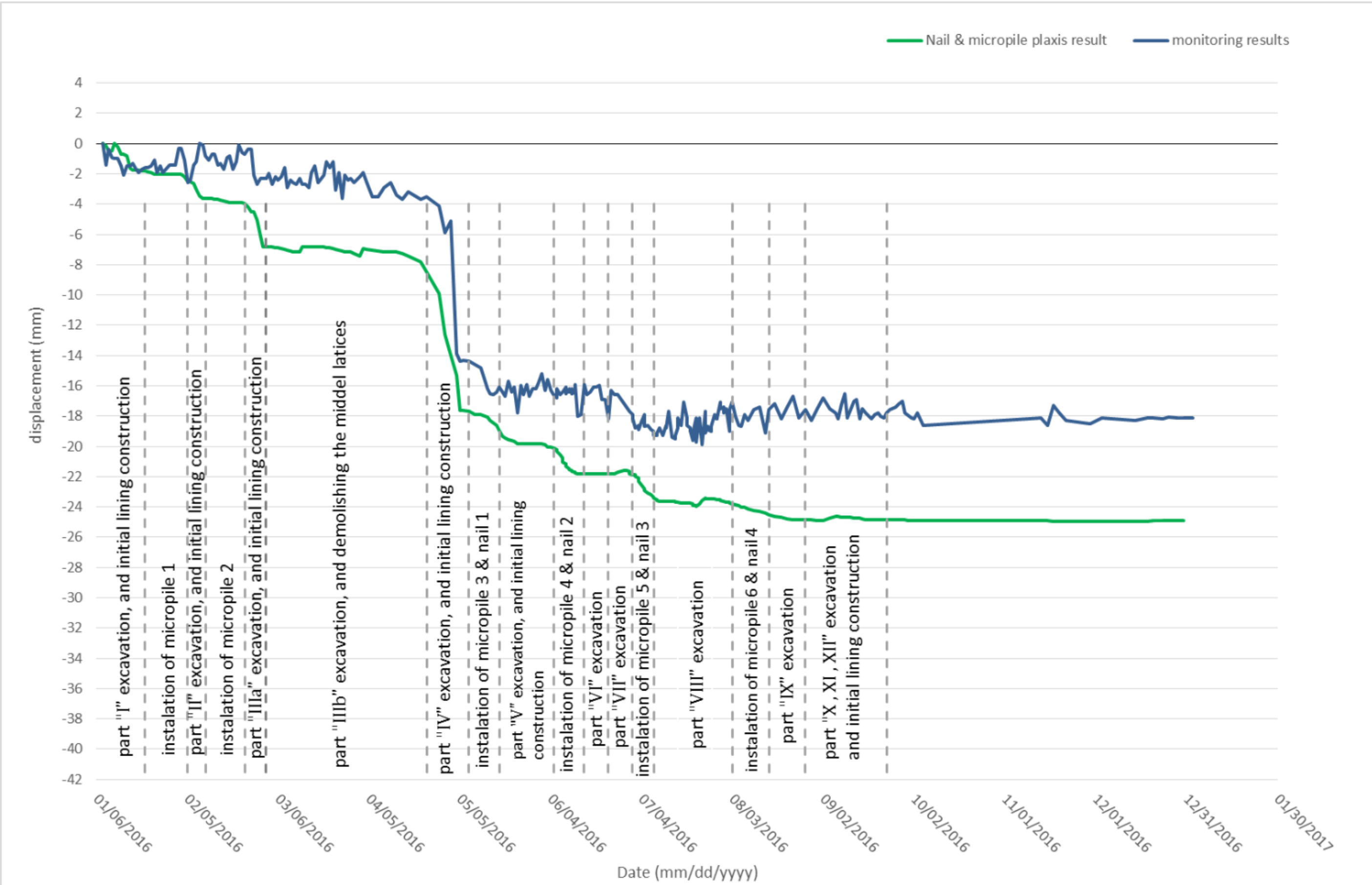
Model NO.	cases			Surface Displacement		Initial Lining Maximum Bending Moment	
	Fore pole	Micro pile	nail	Surface vertical disp. (mm)	Reduction percentage compared to NO.1	Maximum Bending Moment (kN.m/m)	Reduction percentage for compared to NO.1
1	-	-	-	-51.35	-	165.39	-
2	✓	-	-	-39.03	24%	116.25	29.7%
3	-	✓	-	-40.41	21%	158.34	4.26%
4	-	-	✓	-45.79	10.8%	148.56	10.2%
5	✓	✓	✓	-24.90	48.5%	89.95	45.6%

Modares Tunnel

TECHNICAL PROJECT INNOVATION - OF THE YEAR -

- **Monitoring & Numerical simulation ground settlement data comparison**

Difference between results might be due to better soil condition at this part of project comparing to the information obtained from geotechnical studies



Modares Tunnel

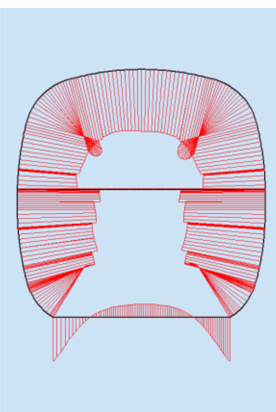
TECHNICAL PROJECT INNOVATION - OF THE YEAR -

Internal forces induced in final lining

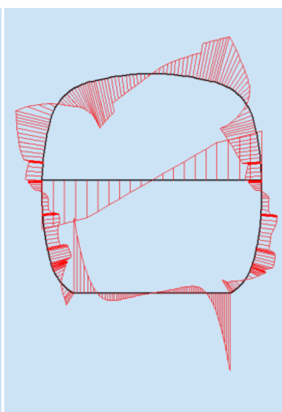
- Quasi-static analysis performed based on Tunneling and underground space technology report of "Hashhash". The shear stress mentioned in following table applied to MDE and ODE models.

Seismic risk level	Return period (year)	Horizontal acceleration (g)	Shear stress $({}^{kN}/_{m^2})$
ODE (probability of exeedence 50%)	144	0.24	115.2
MDE(probability of exeedence 5%)	3283	0.65	173

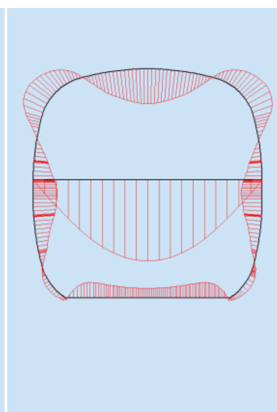
Static loads			Dynamic loads (ODE)		



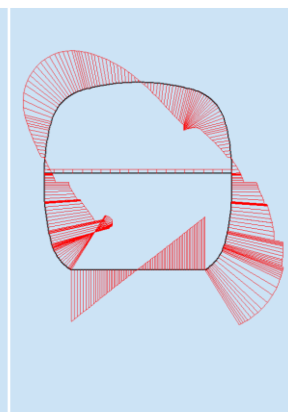
Axial forces
Extreme axial force -667.09 kN/m



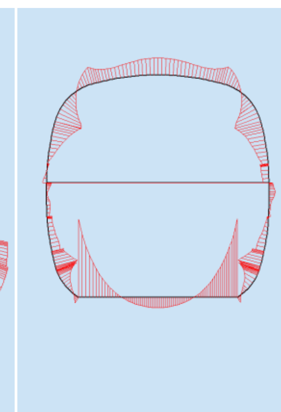
Shear forces
Extreme in plane shear force -267.01 kN/m



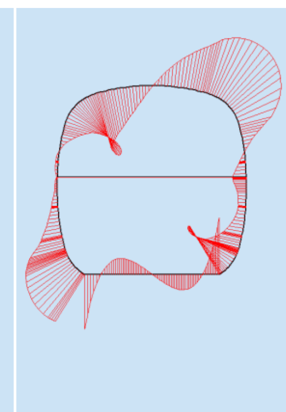
Bending moments
Extreme bending moment 583.23 kNm/m



Axial forces
Extreme axial force -861.20 kN/m



Shear forces
Extreme in plane shear force 467.45 kN/m



Bending moments
Extreme bending moment -347.59 kNm/m

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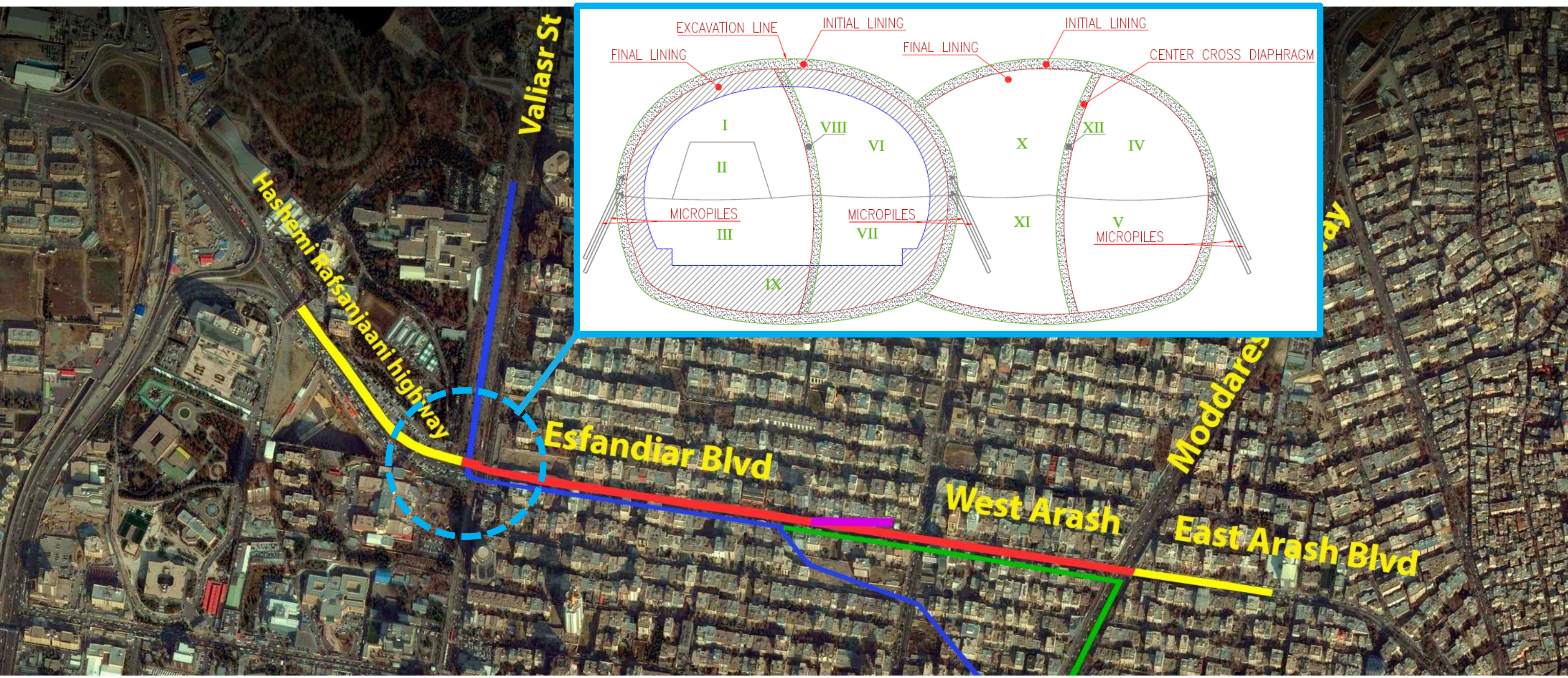
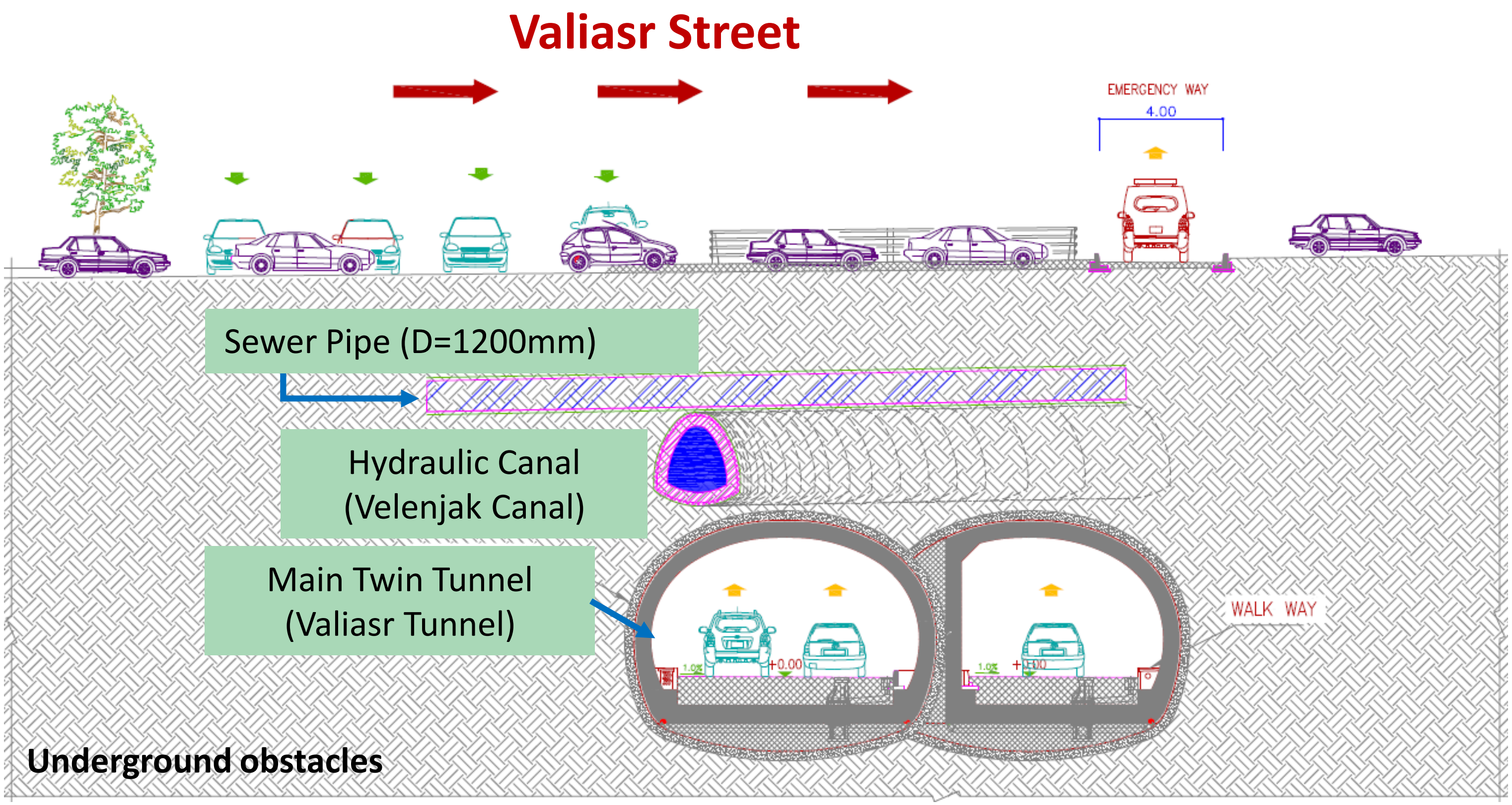
TECHNICAL PROJECT INNOVATION - OF THE YEAR -

Valiasr Tunnel:

- Twin tunnel with the length of 50 m, 18.3m width and 8m height and the overburden of 12 m,
- Under passing Valiasr Street
- Ground settlement restricted to allowable limit



- **Valiasr Tunnel:** a unique rather flat cross section (Twin tunnel) under Valiasr Street.
- Existence of some underground obstacles adjacent to the tunnel



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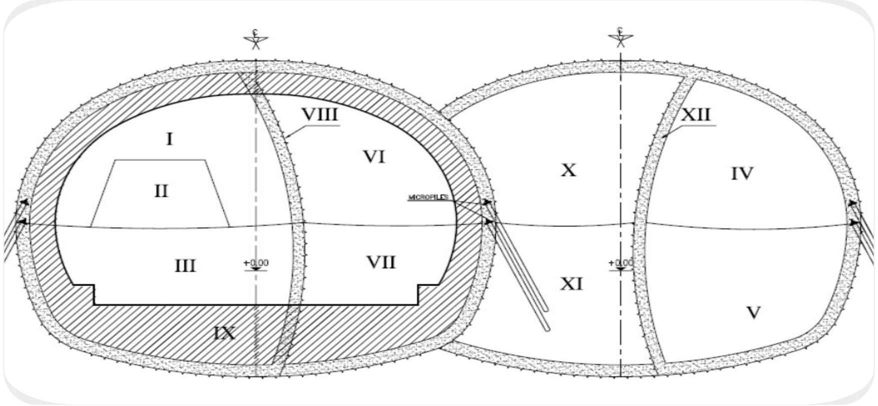
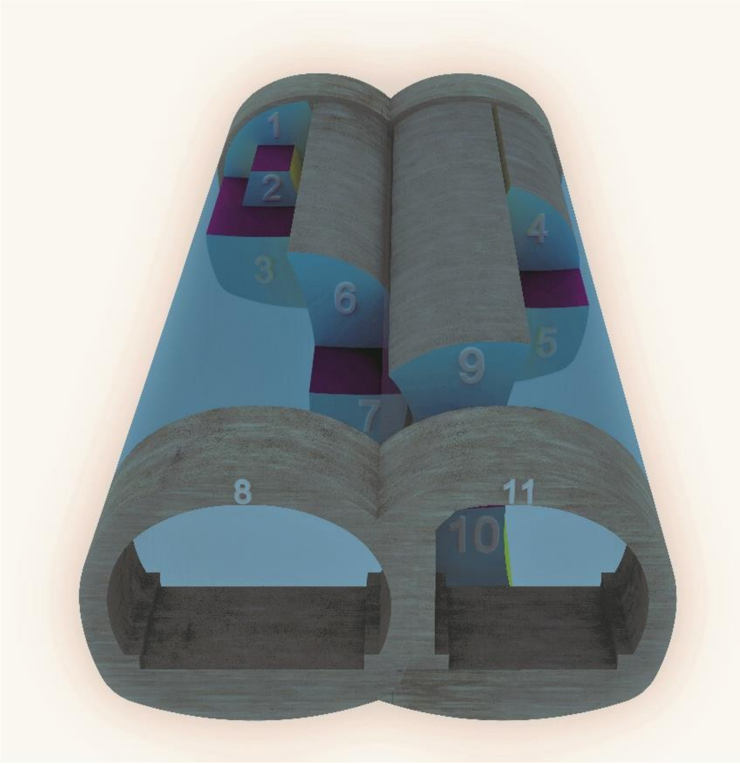
TECHNICAL PROJECT INNOVATION - OF THE YEAR -

- **Valiasr Tunnel:** a unique rather flat cross section under Valiasr Street. Combination of NATM, nailing and final lining of the left tube in order to reach a safe construction





- **Valiasr Tunnel:**

Three numerical models were simulated for Valiasr Tunnel excavation process;

Model NO.	Extra Supporting Systems	
	Micropile	Final lining of the left tube before complete excavation of right tube
1	-	-
2	-	✓
3	✓	✓

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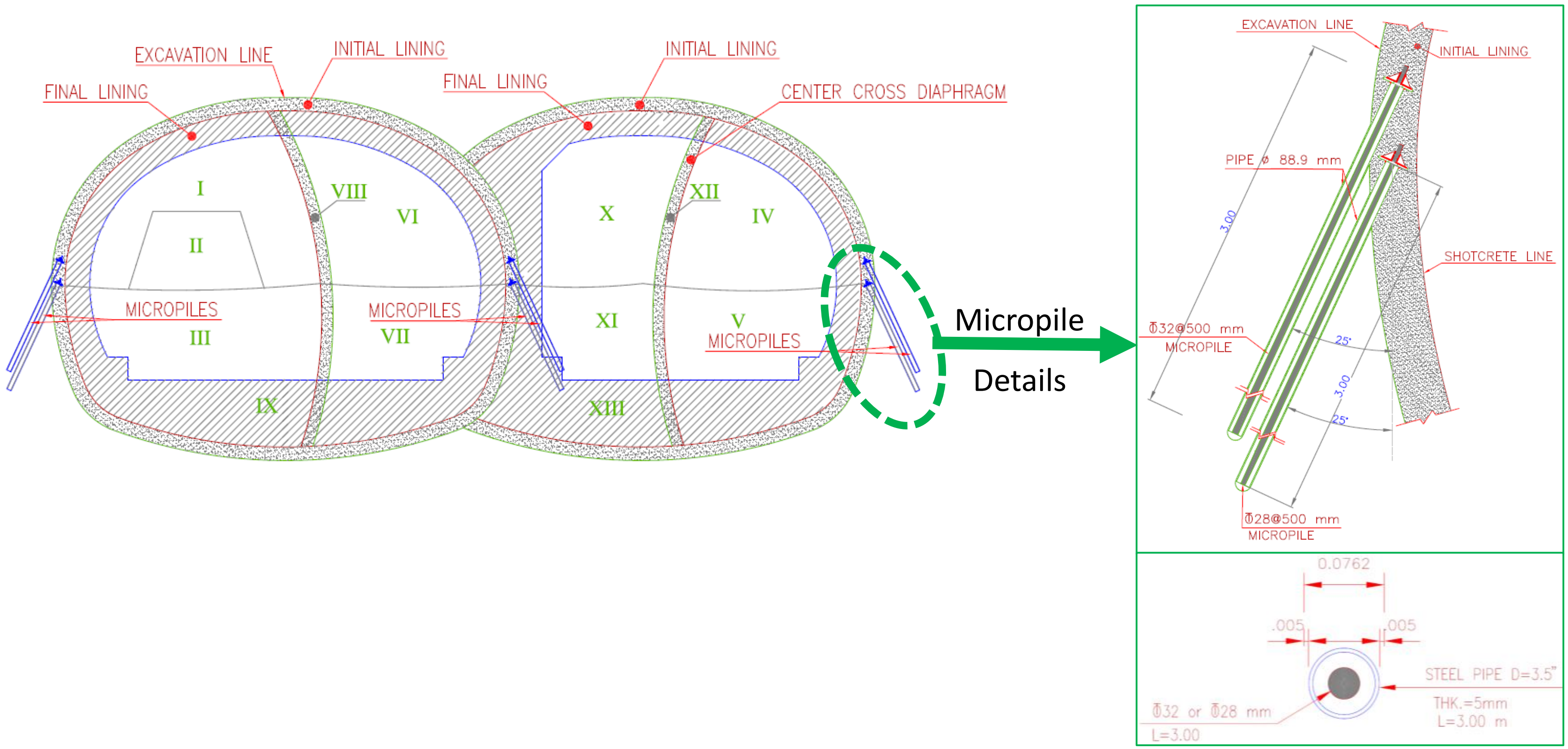
Valiasr Tunnel

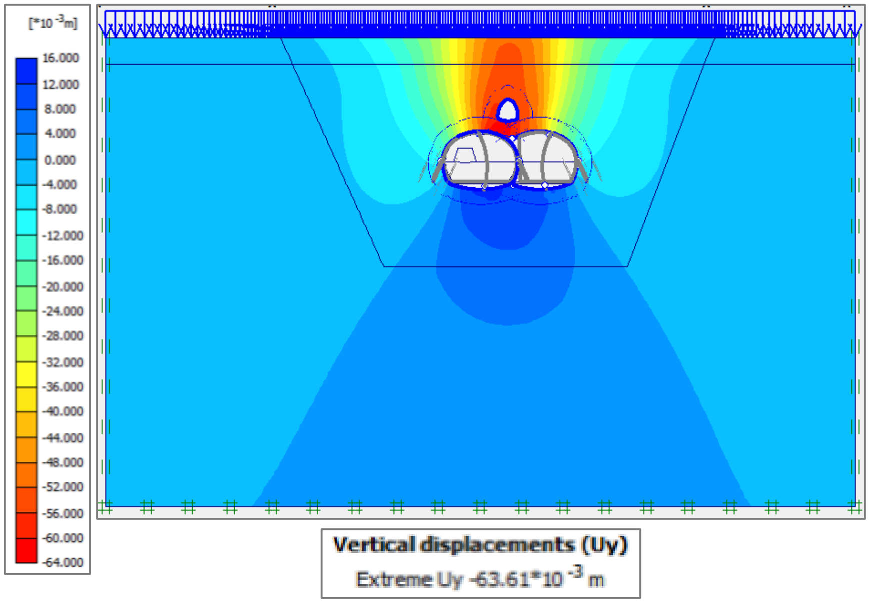
TECHNICAL PROJECT INNOVATION - OF THE YEAR -

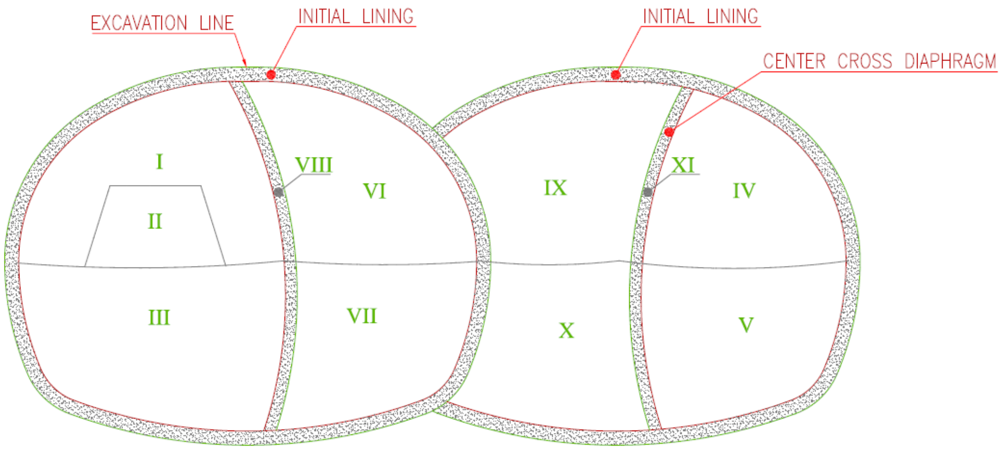
Stages of Construction & Support specifications



Valiasr Tunnel

- **Model No. 1 (NATM method, no extra supporting system)**



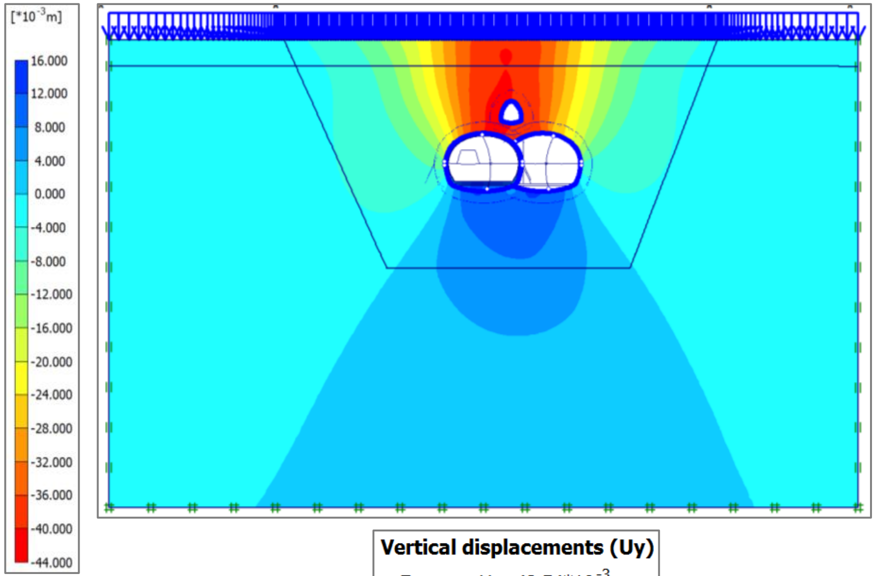


More than allowable settlement →

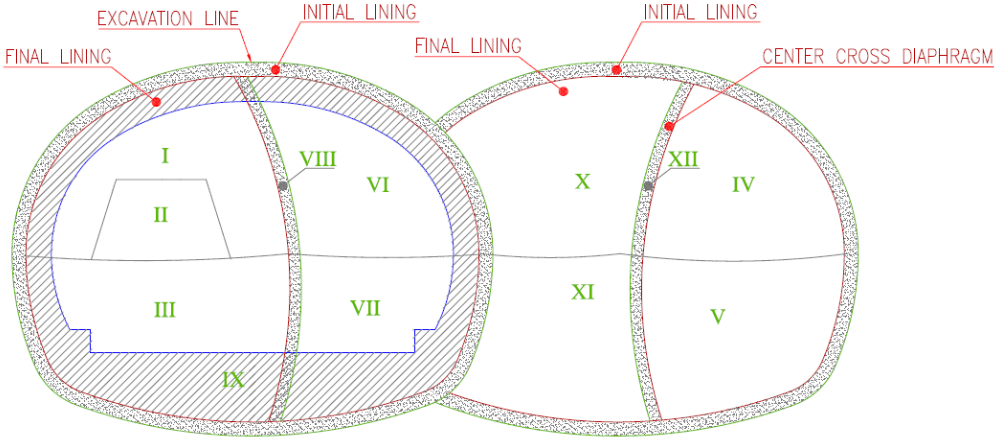
Allowable surface settlement (mm)	25.4
Maximum total vertical displacement (mm)	63.6
Maximum surface settlement (mm)	51.3

Valiasr Tunnel

- **Model No. 2 (NATM method with final lining of the left tube before complete excavation of right tube)**



Vertical displacements (Uy)
Extreme Uy -43.54*10^{-3} m



Allowable surface settlement (mm)	25.4
Maximum total vertical displacement (mm)	43.5
Maximum surface settlement (mm)	40.0

More than allowable settlement →

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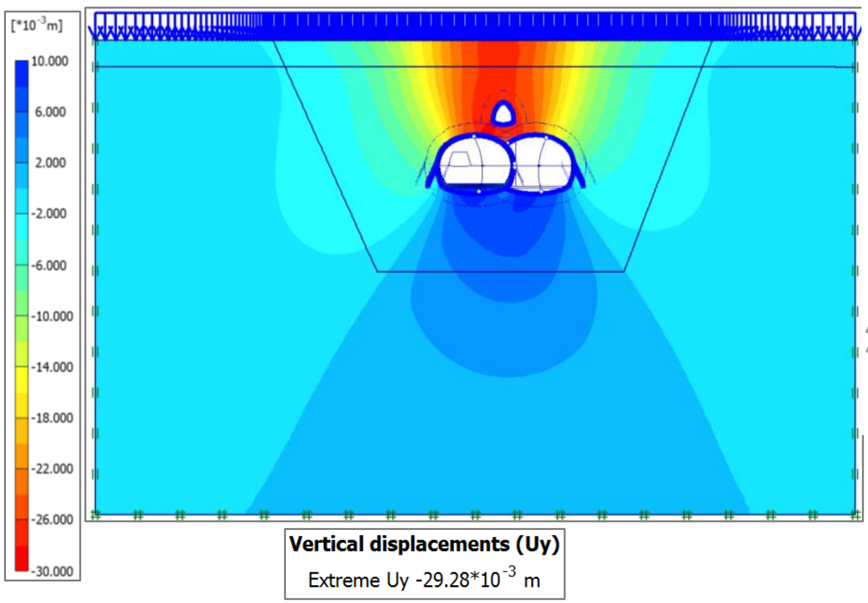
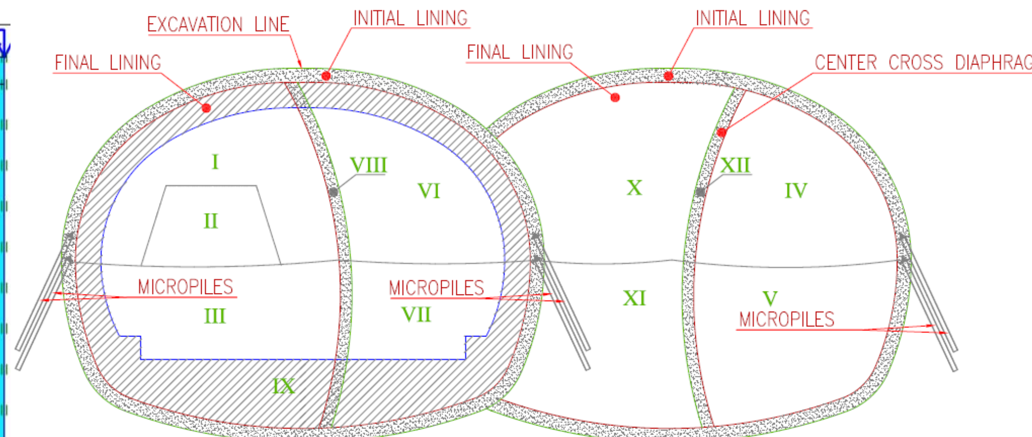
Valiasr Tunnel

- **Model No. 3 (NATM method with final lining of the left tube before complete excavation of right tube and Micro-piles)**





Allowable surface settlement (mm)	25.4
Maximum total vertical displacement (mm)	29.2
Maximum surface settlement (mm)	24.8

Less than allowable settlement → (Maximum surface settlement)

Therefore for construction of Valiasr tunnel (with rather flat cross section), NATM method with final lining of the left tube before complete excavation of right tube and Micro-piles were used.

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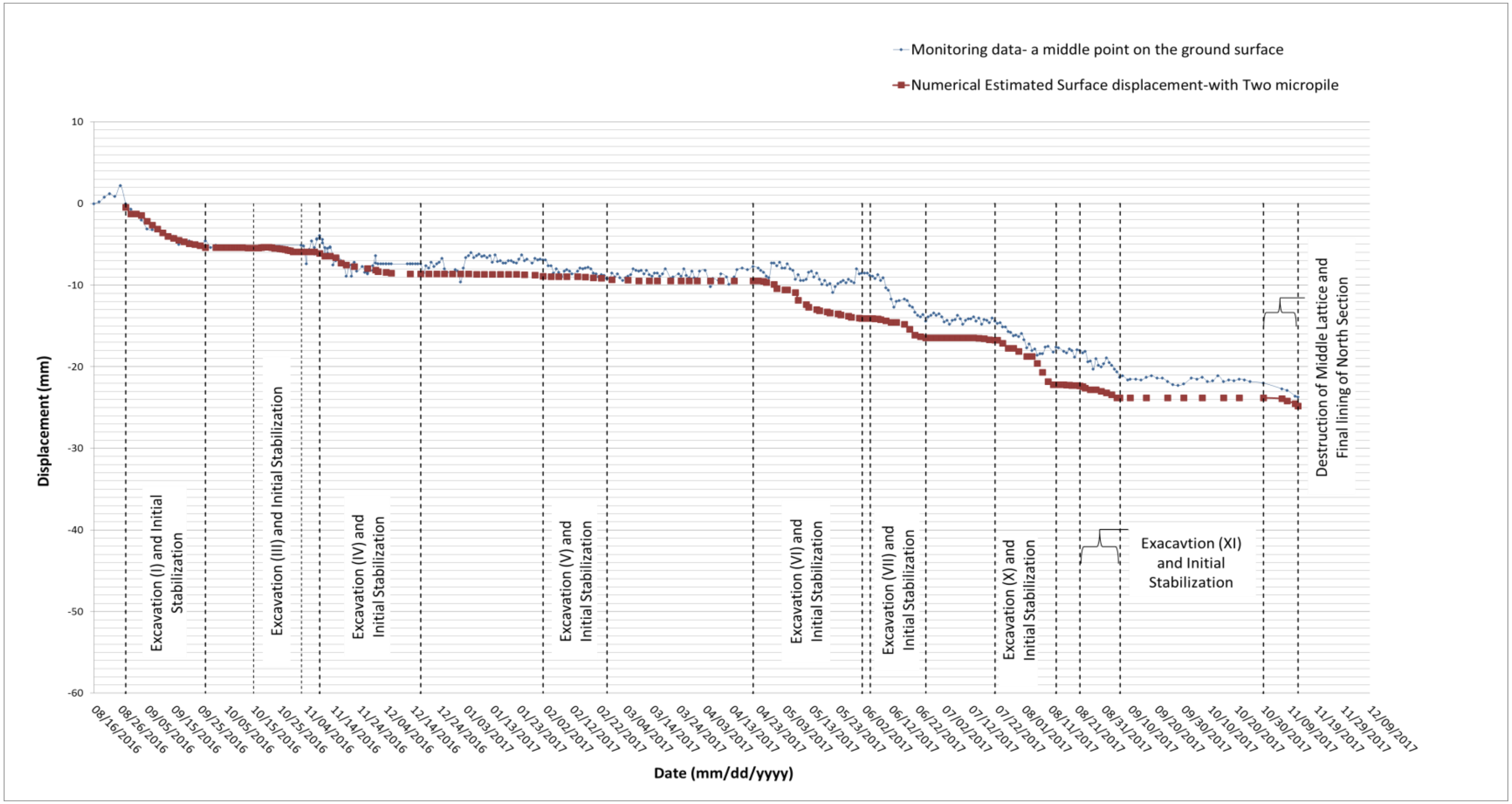
Valiasr Tunnel

TECHNICAL PROJECT INNOVATION - OF THE YEAR -

- **Comparing Model 3 numerical results with Monitoring**

Good agreement between monitoring data and numerical results for different stages of excavation



Conclusions

- Existence of several section transitions and bifurcation owing to the compulsion for unifying various level and non-levels traffic routs,

- Combination of different supporting approach including NATM, soil improvement (fore-poling, micro-pile, grouting, nailing) and partially final lining of the cross section before complete excavation simultaneously in order to reach a safe construction for a rather flat cross section (i.e., Valiasr tunnel) and a rather square cross section (i.e., Modares tunnel) which are far from rounded sections (rounded sections initiate confinement forces and limit internal forces in the lining, also allows the smooth flow of stress into the ground around the tunnel and causes less displacements)

- No disruption and acquisition of surface ground especially during construction of two main parts of the project i.e., Modares tunnel and Valiasr tunnel