ITA - AITES WORLD TUNNEL CONGRESS 2007 PRAGUE

The 3rd Training course
TUNNELLING IN URBAN AREA
Prague, 4-5th May 2007

Conventional Tunneling in Urban Area – Case History and Future Prospect in Japan

TRAINING MATERIAL PREPARED BY

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AITES
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INTERNATIONAL TUNNELLING ASSOCIATION

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Conventional Tunneling in Urban Area

Introduction

Conditions considered for planning of tunnels

1. Geometry (Length, Depth, Size)
2. Geological conditions (Soil, Rock, Water)
3. Surface conditions (urban area, mountains)
4. Access to the tunnels (Size of Access Roads)
5. Construction schedule

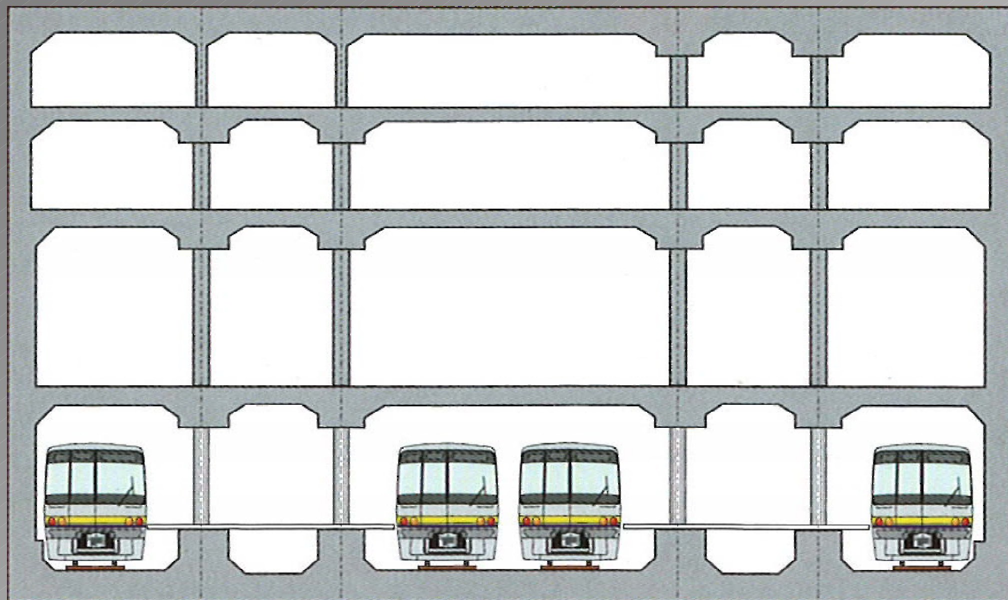
1.Geometry

Usage of Tunnels in Urban Area in Japan

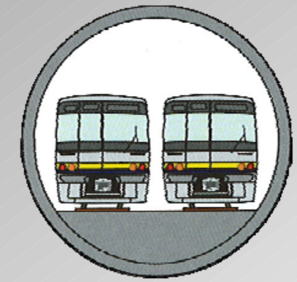
Usage	Typical Area (m2)	Remarks
Railroad	20 to 90	20m2 for light rail, 90m2 for double track bullet train
Road (Expressway)	70 to 200	Expressway 2 traffic lanes and 1 parking lane
Road (Highway)	50 to 100	National highways
Underground River	100 to 300	Used as a reservoir too
Water	up to 10	Relatively small
Sewer	up to 30	Main is 6 to 8m in diameter
Power	up to 10	Relatively small
Gas	up to 10	Relatively small
Combined Utility	10 to 25	Size varies
U/G Railroad Stations	Very large	Constructed by Cut and Cover Methods
U/G Shopping mall	Very large	Constructed by Cut and Cover Methods
U/G Parking Garages	Very large	Constructed by Cut and Cover Methods

Introduction

Cross section of various tunnels



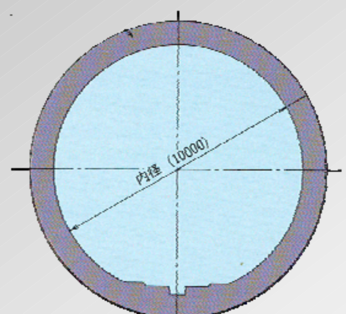
U/G Railroad Stations



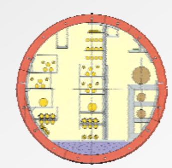
Railroad (double track)

Railroad (single track)

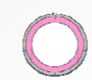
Expressway



Underground river



Combined Utility



Sewer

Conventional Tunneling in Urban Area

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2.Geological Conditions

a. Geology

Soil	Sand and Gravel
	Clay
Rock	Hard Rock
	Soft Rock
	Fractured
	Swelling

b. Overburden Depth

Shallow	Subsidence
Deep	High Pressure

c. Ground Water

Water Pressure	
Flow Amount	

Introduction

3.Surface Conditions

- Mountains
- Hills and Forest
- Farmlands
- Urban Area
- Heavily Crowded Area
- Adjacent Important Structures

4.Access to the tunnels

- Construction Area
- Access Roads

5.Construction schedule

Construction Methods of Tunneling

Conventional

- Drill and Blast
- Mechanical Excavation

Mechanized

- Hard Rock TBM
- Tunnel Bore Expander
- Soft Ground TBM

Comparison of Construction Methods

Conditions		Mechanized	Conventional
Geometry	Large Cross Section	Up to 16m D	□ ›
	Variable Cross Section	×	□ ›
	Short	□ ˘	□ ›
	Long	□ ›	□ ˘

Geology	Soil	Sand /Grave	above GWL	□ ›	□ ˘
			below GWL	□ ›	×
		Clay		□ ›	□ ˘
	Soft Rock			□ ›	□ ›
	Hard Rock			□ ›	□ ›
	Fractured Rock			□ ˘	□ ›
	Swelling Rock			□ ˘	□ ›
	High Water Pressure			Up to 1.0Mpa	Dewatered

Subsurface Settlement		□ ›	□ ˘
Access	Construction Yard	Large	Small
Speed		□ ›	×

Conventional Tunneling in Urban Area

Introduction

Introducing Conventional Tunnelling in urban Area Case Histories in Japan

Case History 1 : Onmawashi Park Underground Reservior Project

Large cross section, Various size, Low overburden depth

Case History 2 : Nagoya Expressway Higashiyama Tunnel

Sandy soil, Under the residential area, Large Junction

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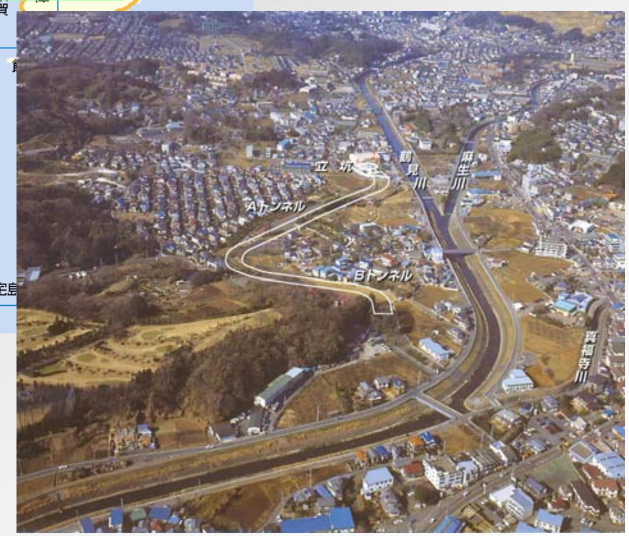
Case History 1

Onmawashi Park Underground Reservoir Project

Project Outline

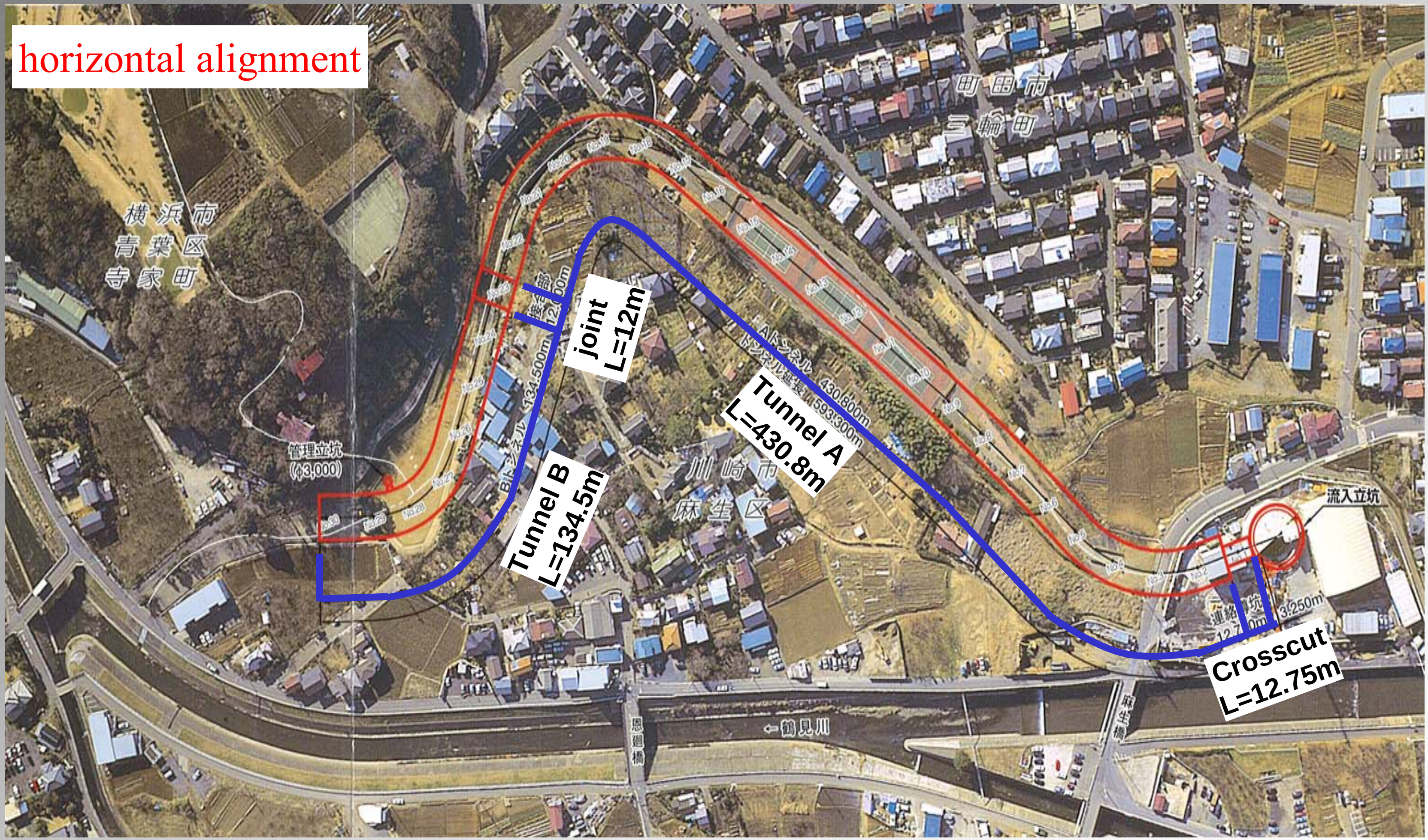


Conventional Tunneling in Urban Area

Project Outline

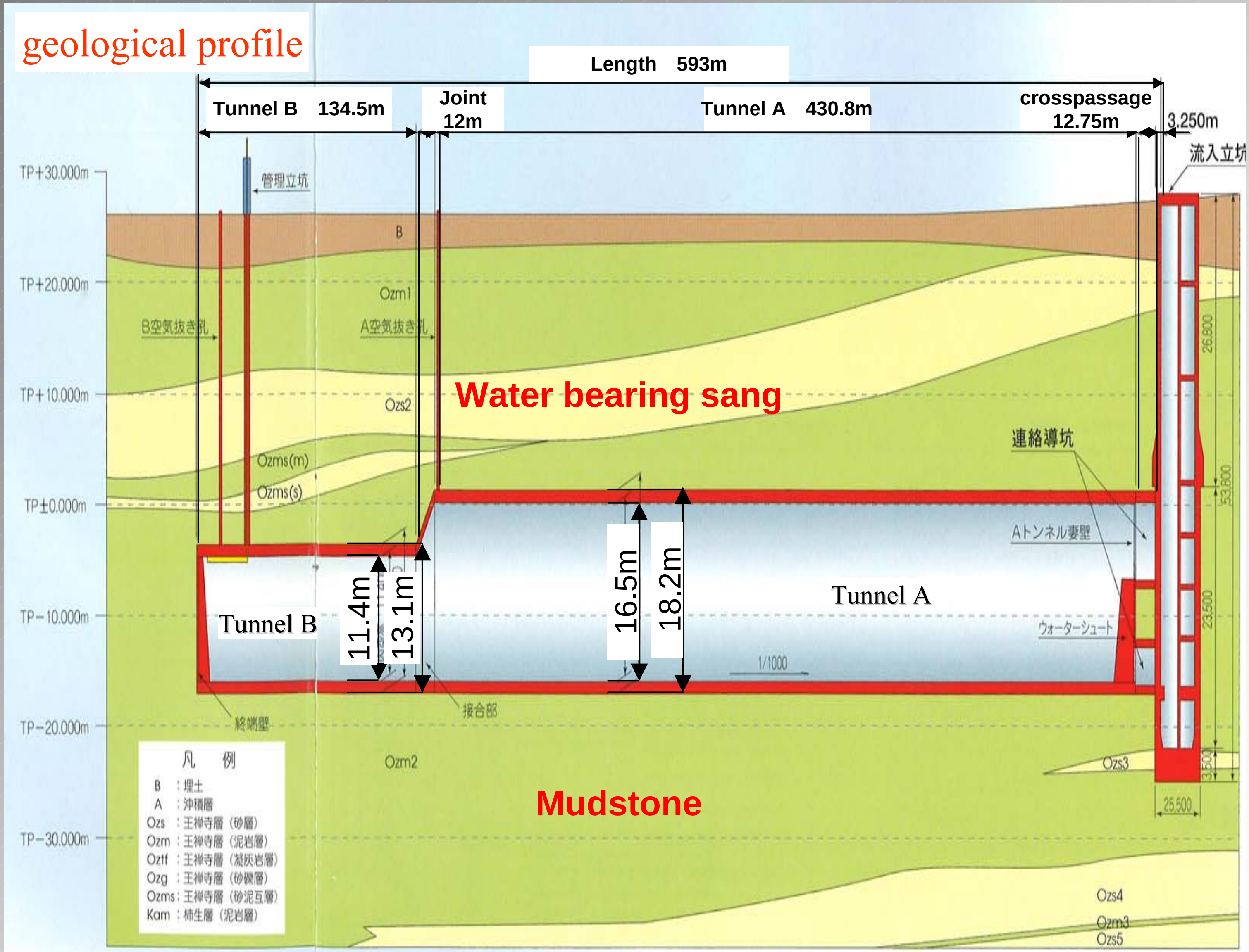
Project Name	ONMAWASHI-KOEN Flood Control Tunnel	
Client	KANAGAWA Pref.	
Usage	Flood Control Tunnel	
Length Cross Sectional Area	Section A	430.8m, 254.1m^2
	Section B	134.5m, 166.7m^2
	Construction Joint spacing	12.0m
	Upper crosscut	12.75m, 58.7m^2
	Lower crosscut	430.8m, 18.5m^2
Excavation Method	Top Heading & Multiple Bench NATM with Advancing Center Drift	
Auxiliary Method	Long Fore Piles, Foot Piles, Preload Packs, Face Bolts, etc.	

Project Outline



Conventional Tunneling in Urban Area

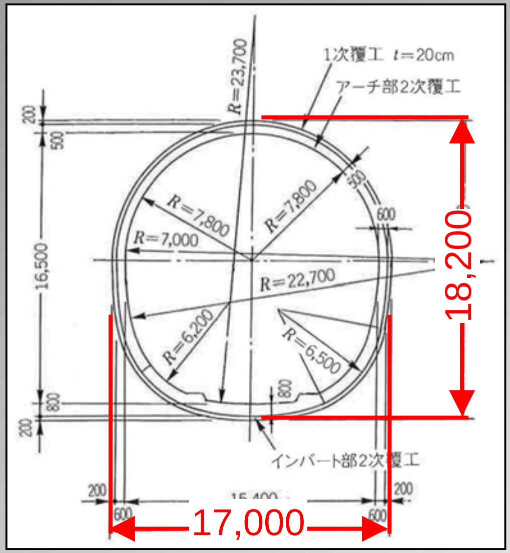
Project Outline



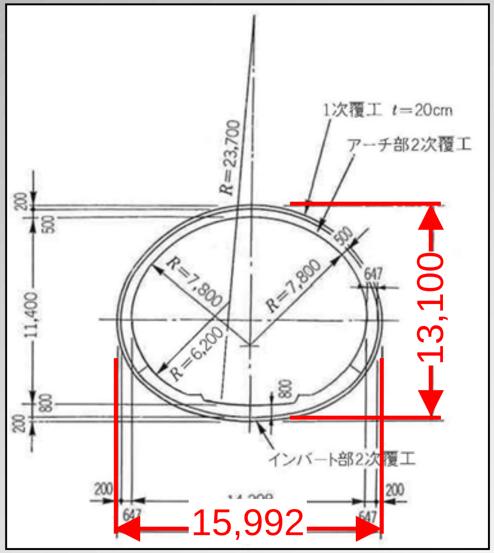
Conventional Tunneling in Urban Area

Features

- Large diameter oblong shaped tunnel for flood control in mudstone.Width:17.2m, Heigth1:8.2m, Cross Sectional Are:254.1m^2
- Surface subsidence is critical since there are many houses on the surface with overburden depth of 1.5D.
- Since there are few experiences, it is difficult to predict the influence of large excavation.



Tunnel A



Tunnel B

Conventional Tunneling in Urban Area

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Evaluation of excavation method

The original design

Excavation method for a standard section

1. Side drift advancing method
2. Top heading advancing method
3. Center diaphragm method

FEM analysis → Side drift advancing method

Test excavation was conducted by 2 "Top heading advancing method" because access to the tunnel is restricted.
(50m section from starting shaft)

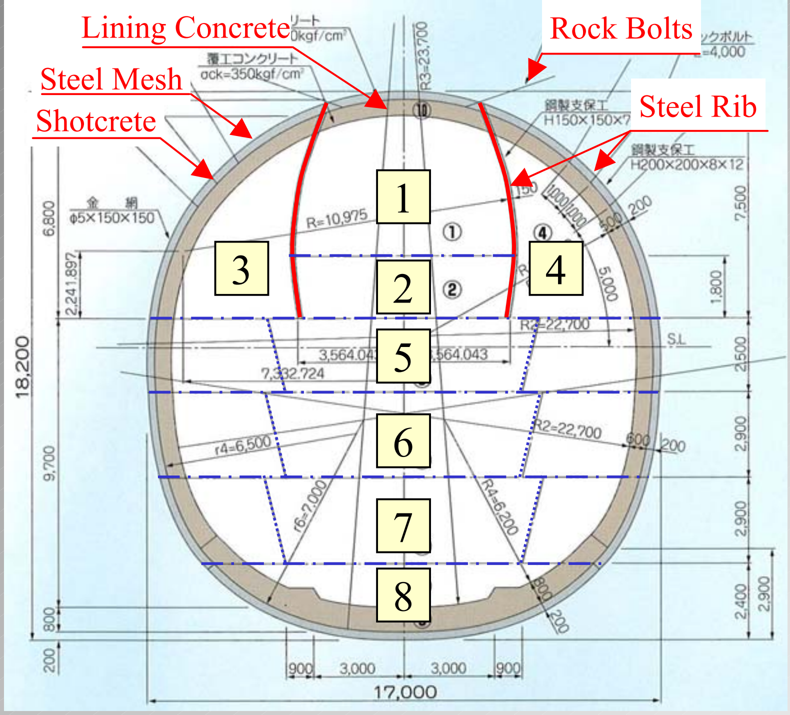
Measurement
- Ground surface settlement
- Convergence
- Ground displacement
- Axial force of support
- Axial force of rock bolt

→ Reevaluation of ground properties

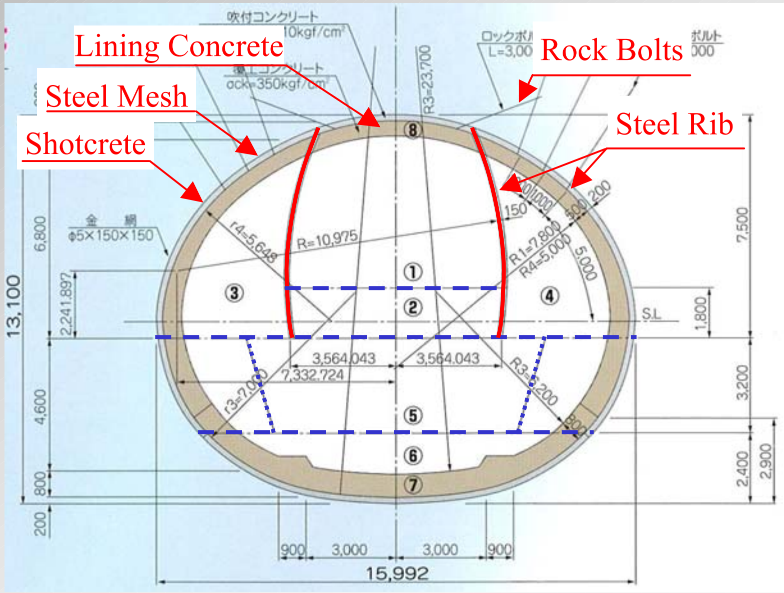
Evaluation of excavation method

The determination of the excavation method of standard section

Top Heading & Multiple Bench NATM with Advancing Center Drift



Tunnel A



Tunnel B

Tunnel cross section

Conventional Tunneling in Urban Area

Enlargement of Top Heading (Test section)

Removing steel support

excavation

Extending steel support

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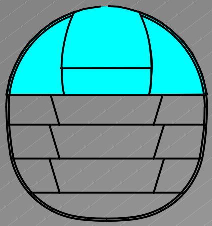
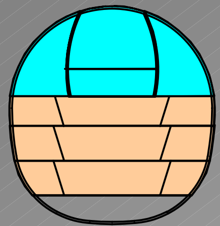
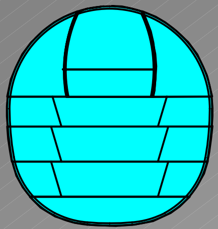
Upper section enlargement

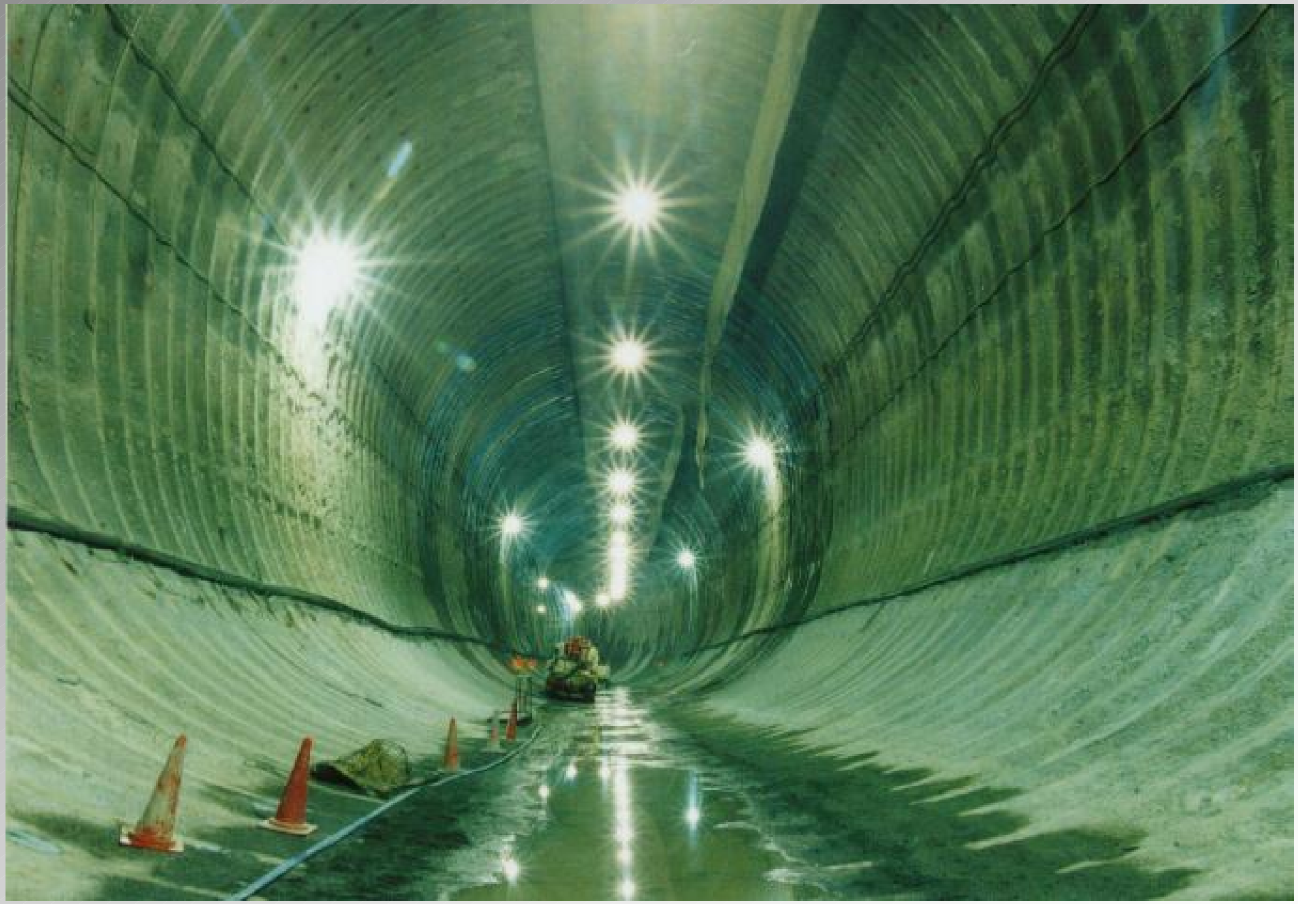


Bottom section excavation

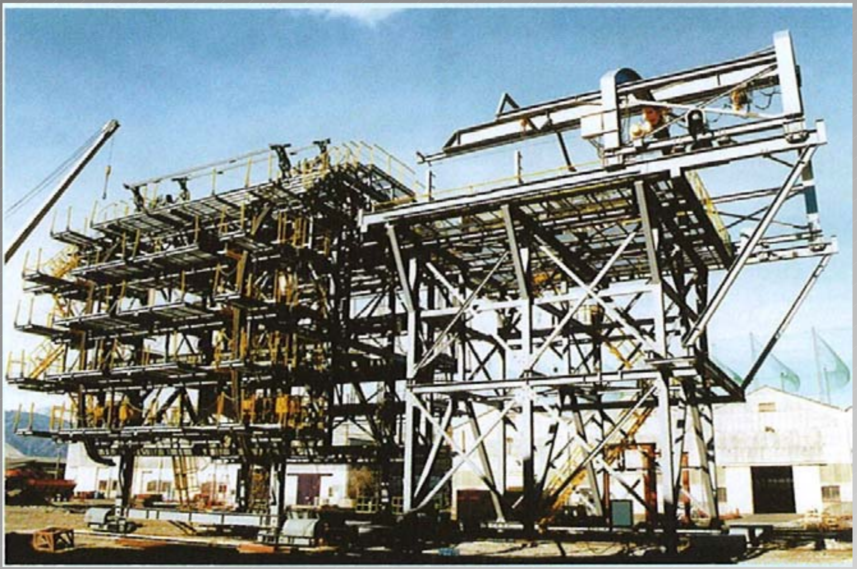


Excavated tunnel

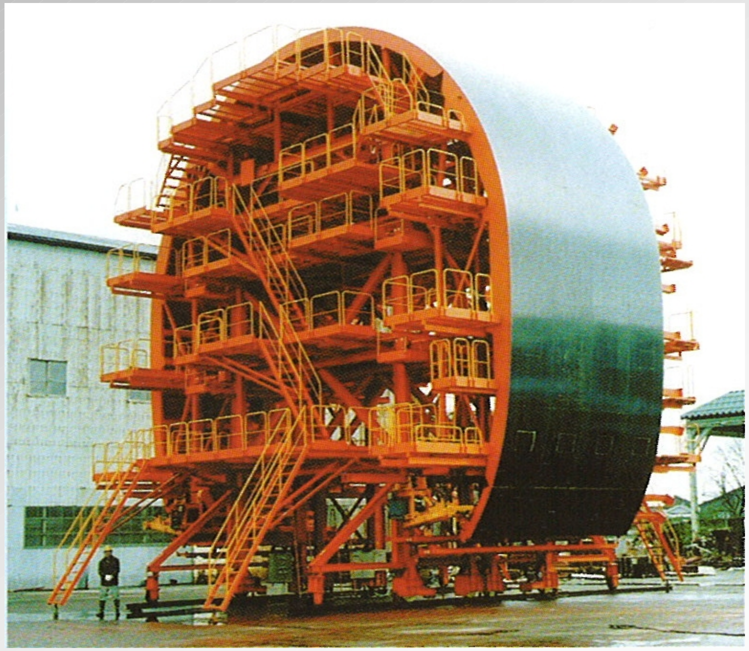




The secondary lining.



The carriage for placing of reinforcement.



Form for tunnel lining

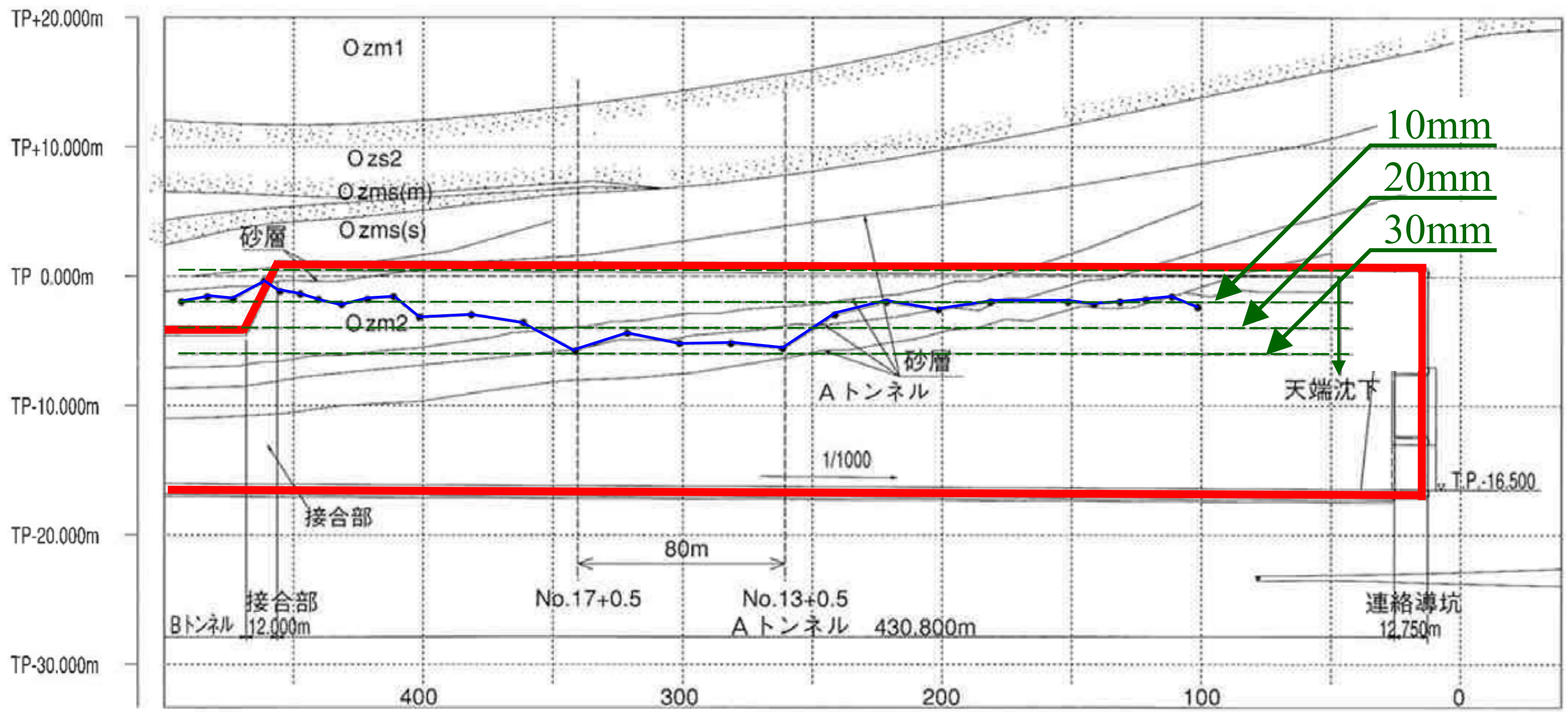
Tunnel A

Tunnel B

Water shute

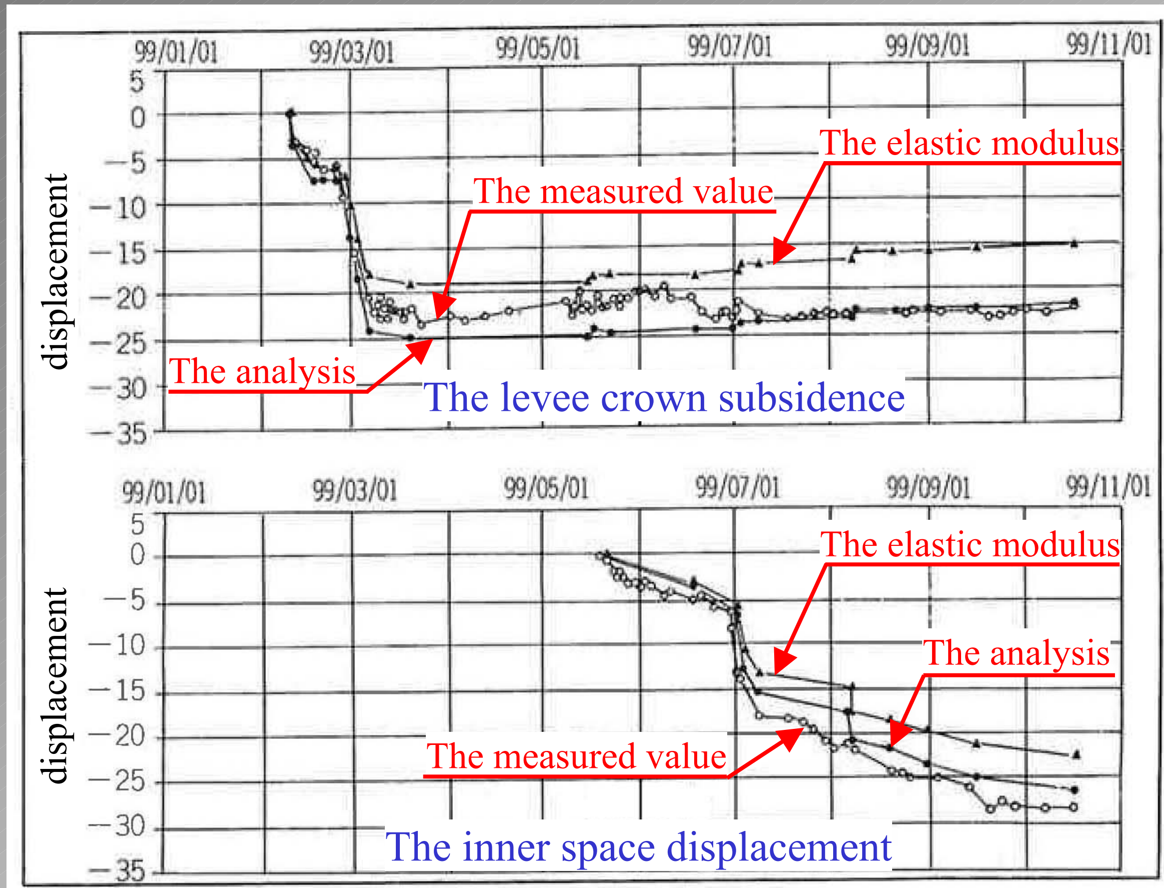
Conventional Tunneling in Urban Area

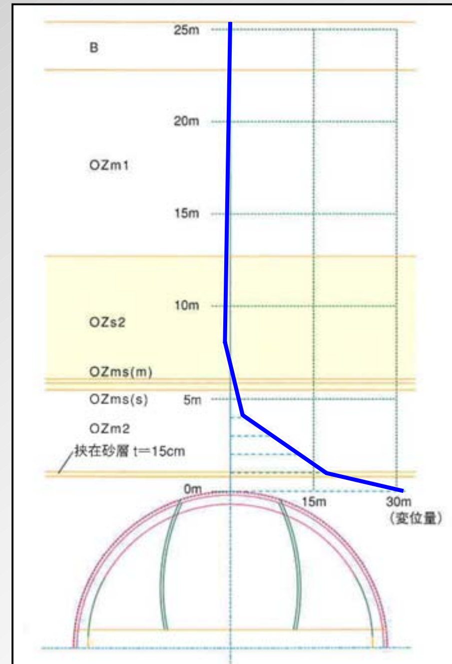
The measuring result



crown settlement

The measuring result





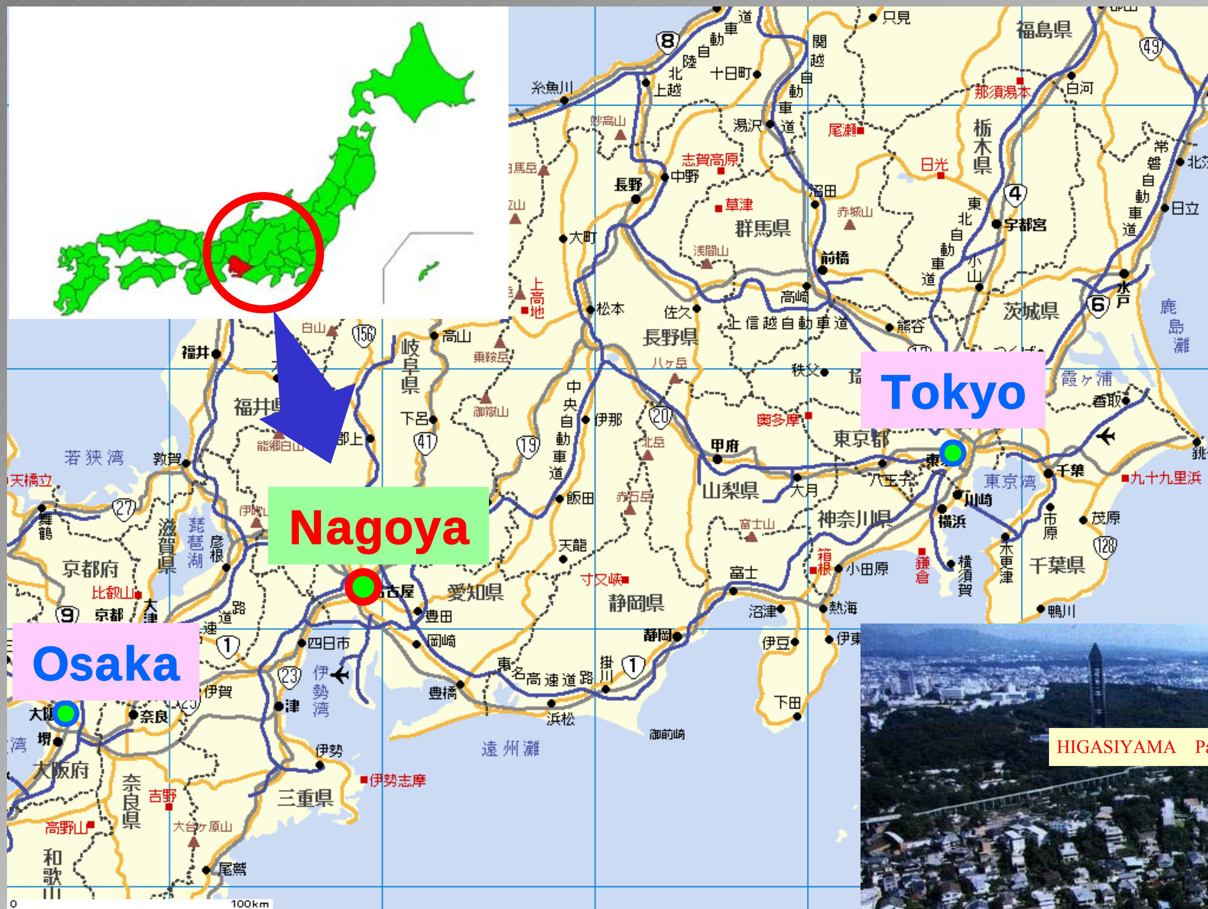
Underground displacement

Case History 2

Nagoya Expressway Higashiyama Tunnel

Conventional Tunneling in Urban Area

Project Outline



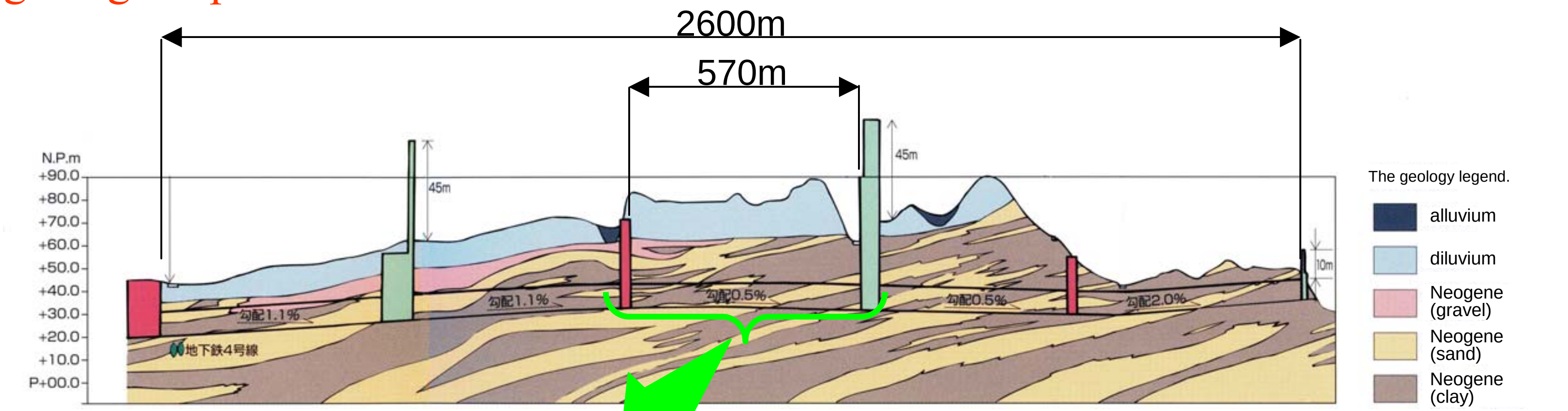
Conventional Tunneling in Urban Area

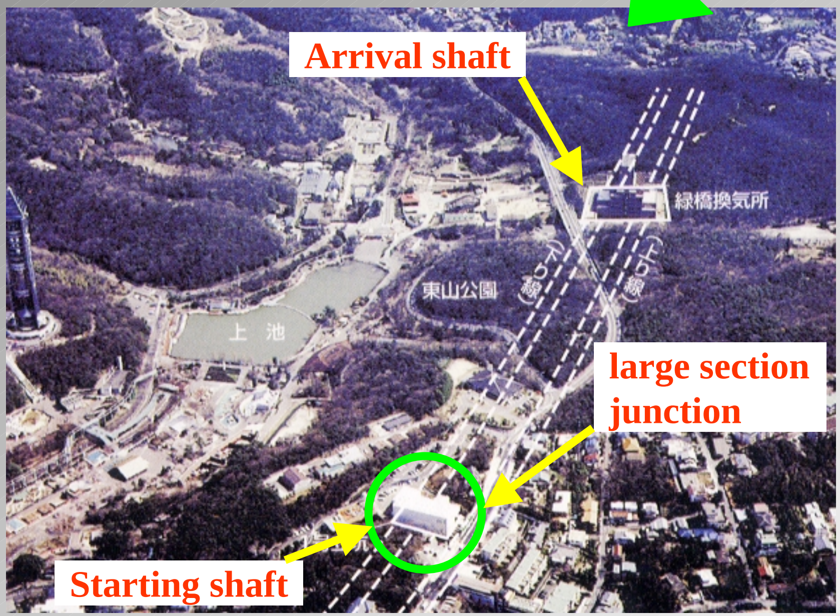
Project Outline

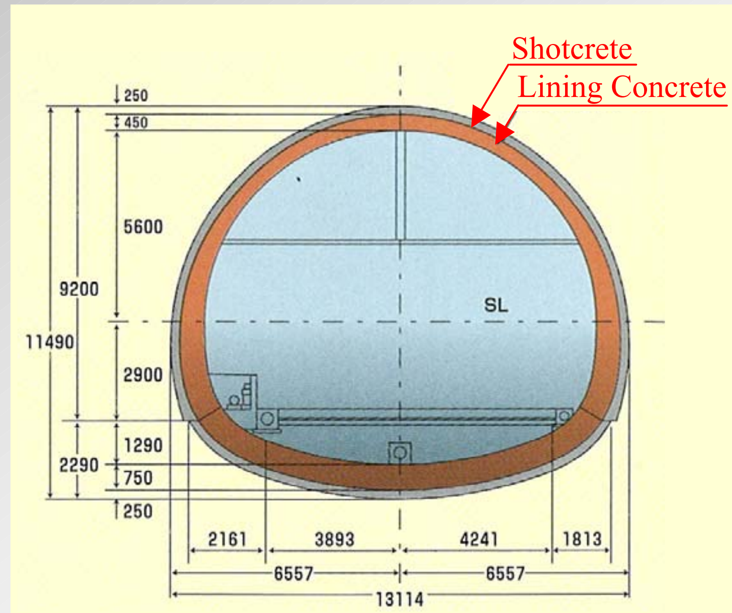
Project Name	Nagoya City Highway No.1 HIGASHIYAMA Tunnel
Client	Nagoya Expressway Public Corporation
Usage	Highway (Two-lane)
Length	2,600m
Cross Sectional Area	114 ~ 136m^2
Excavation Method	NATM
Auxiliary Method	Long Forepiles, Foot Piles, Preload Packs, Face Bolts, etc.

Project Outline

geological profile







Conventional Tunneling in Urban Area

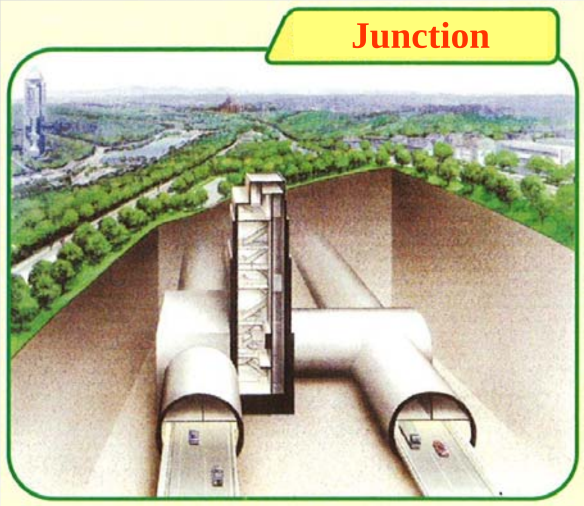
Features

•Two-lane expressway tunnel in sandy and clayey ground with overburden depth of 20 to 40m.

•The underground water level is 5m above the crown, horizontal boring from the heading is conducted to lower the water table.

•Low-rise residential buildings and major trunk roads are on the surface and also the tunnels cross many utility lines.

•One tunnel starts from No.1 shaft, the other starts from the large section junction.



Large junction structure

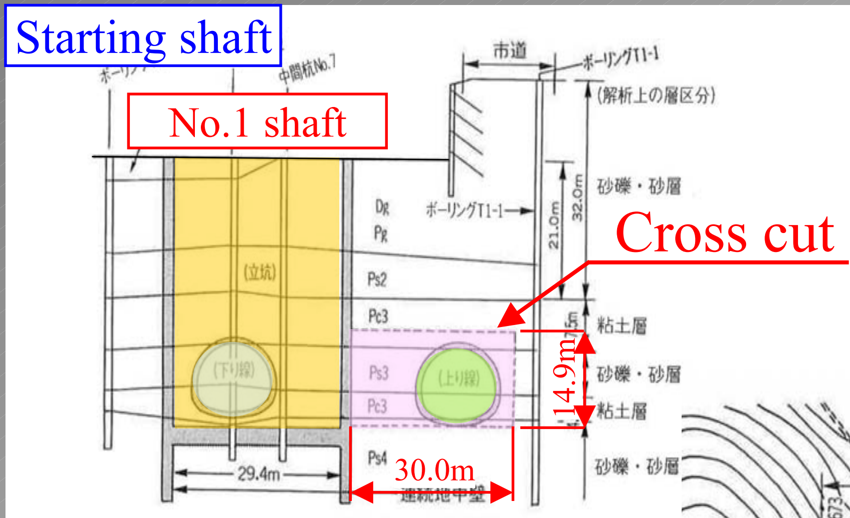


図-12 簡略化した地質縦断図

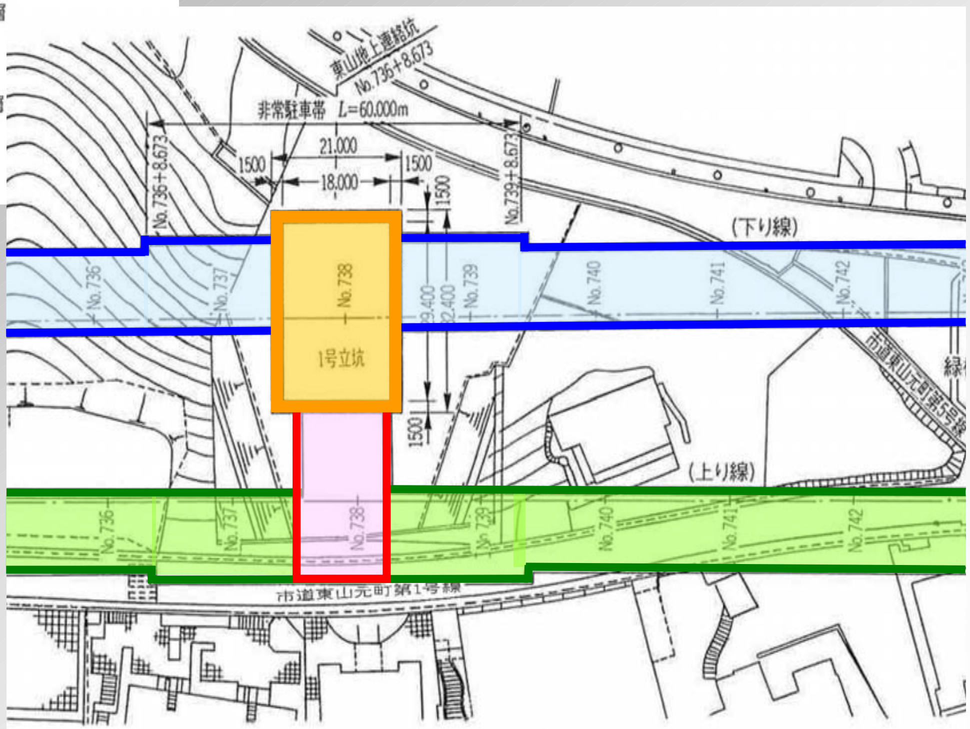
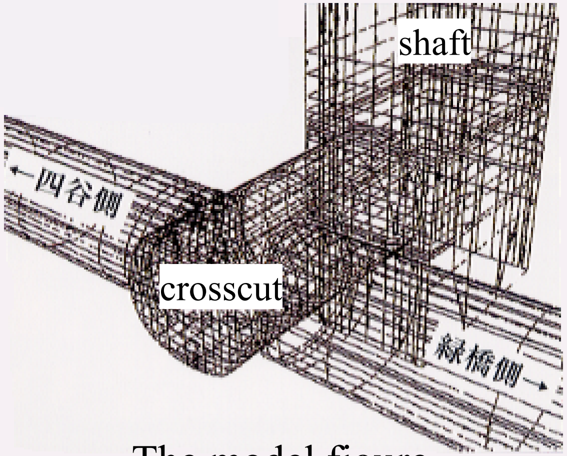
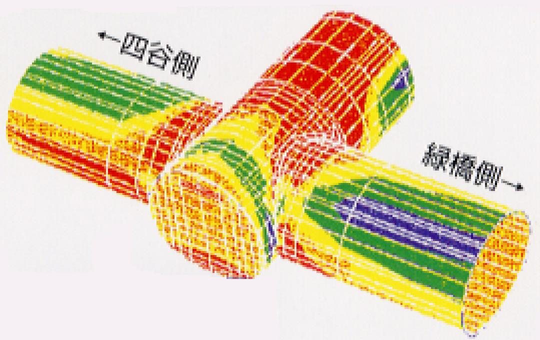


図-9 1号立坑付近平面図

The three-dimensional FEM analysis.



The model figure.



The analytical result

The three-dimensional FEM analysis

The node number:19,740

Number of element:24,297

The ground is modeled in linear elastic solid.

Number of analysis step:26steps

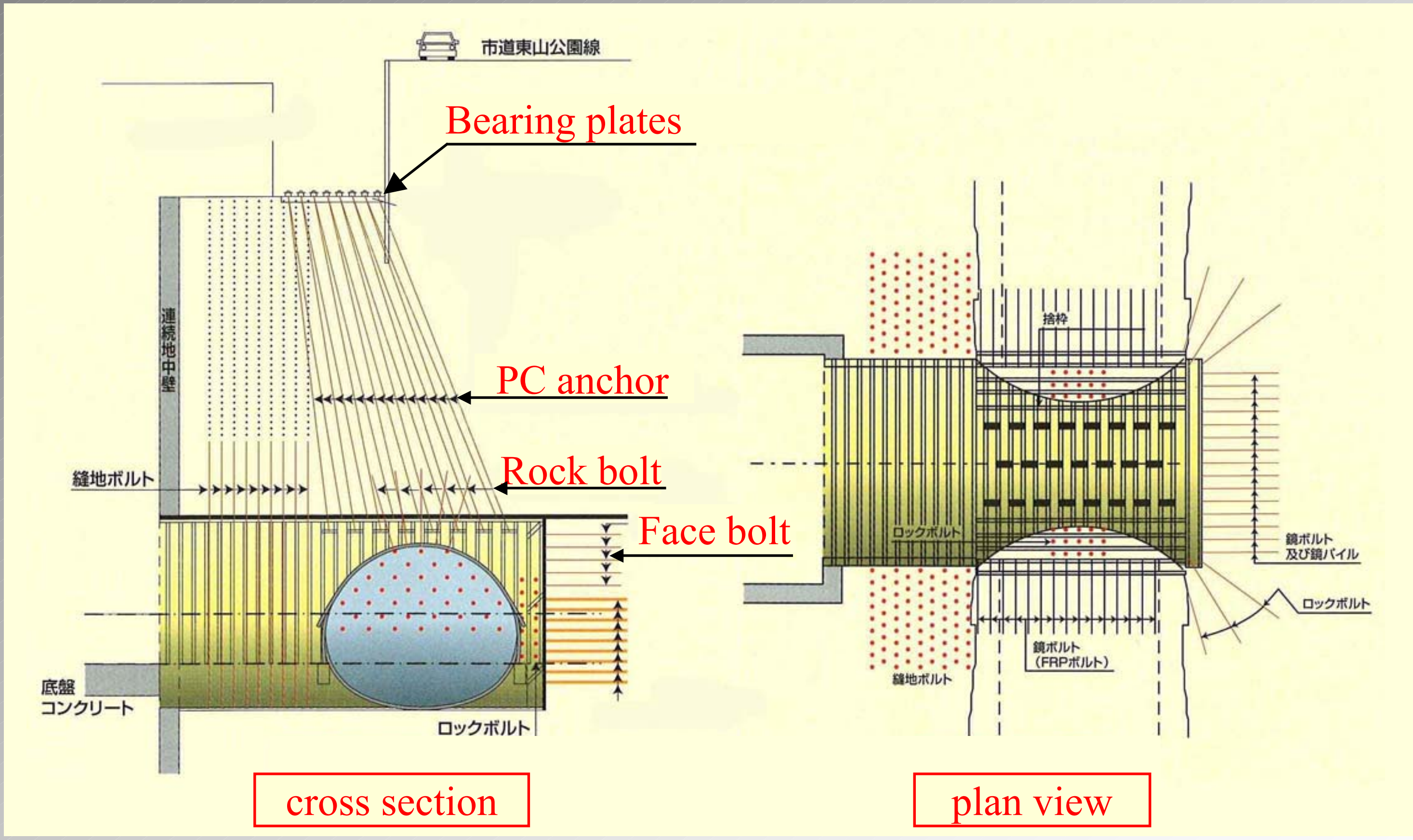
The original design of the auxiliary method and supports are insufficient.

The additional auxiliary method is applied.

The tie-rod method

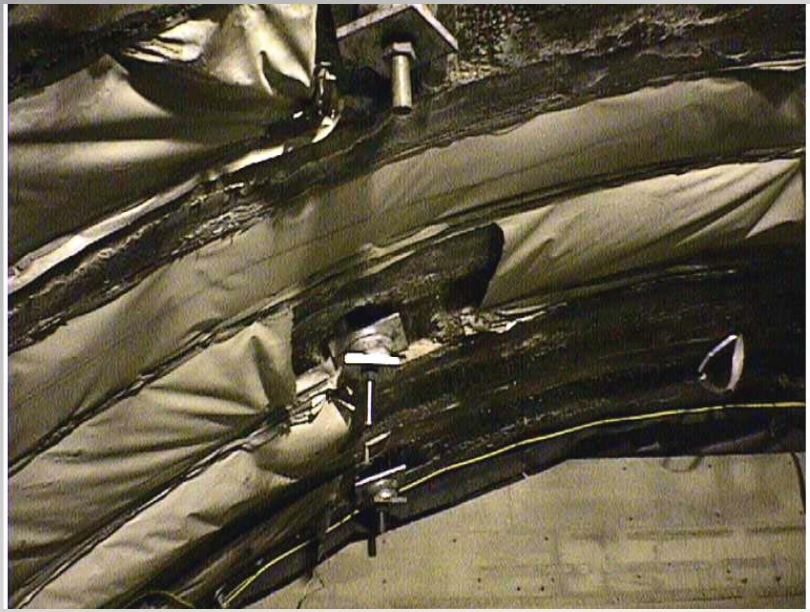
The tie-rod method

The crown is suspended by the anchors from the surface.



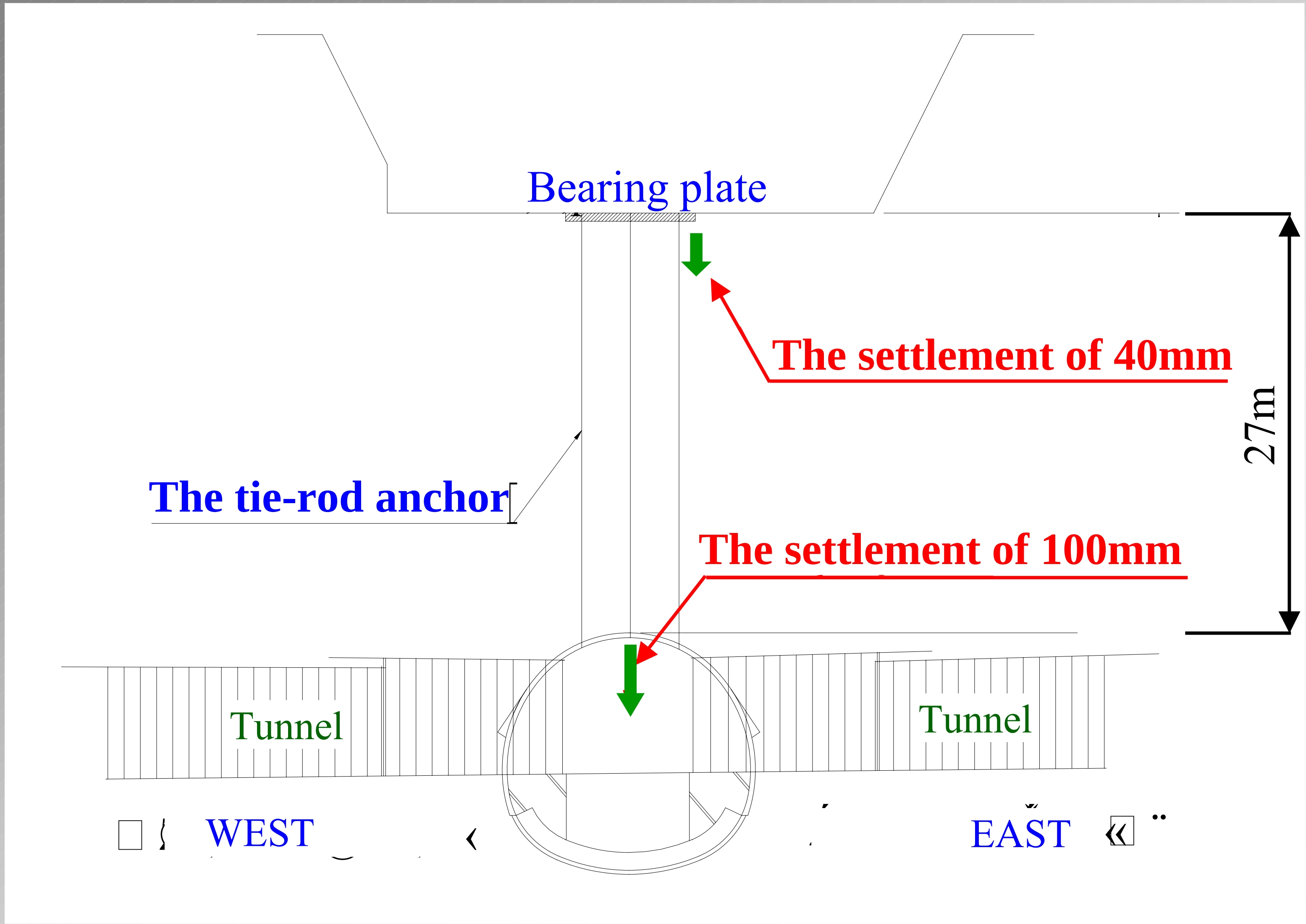
The tie-rod method

Bearing plates and anchors on the surface



Connection of the anchors in the tunnel

The measuring result



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The secondary lining completed

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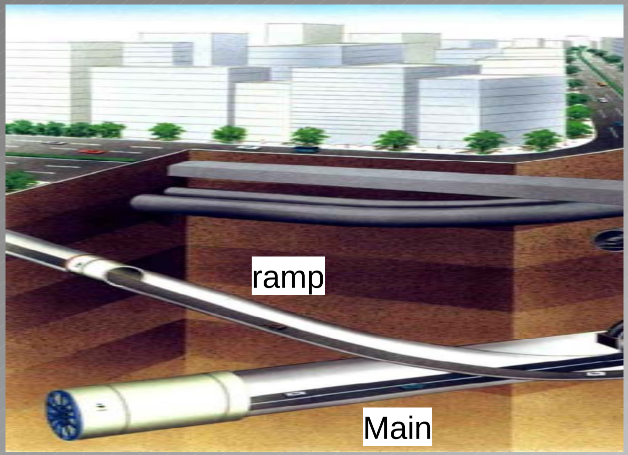
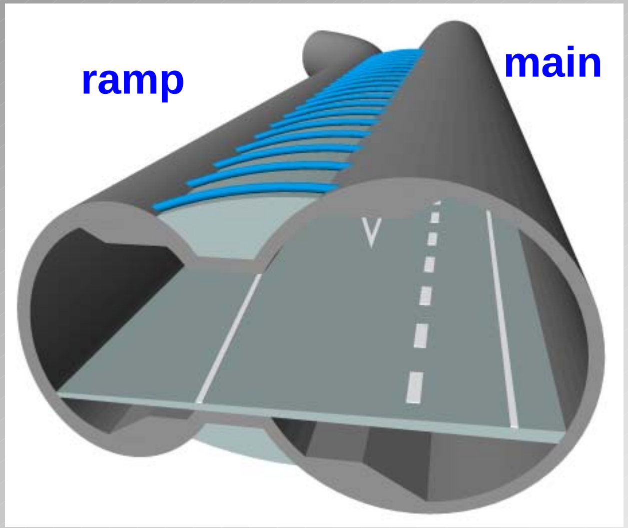
Twin Arch Junction Beams
Combination of mechanized tunnelling and conventional tunnelling

Even if technologies of mechanized tunnelling methods are well developed, still conventional tunnelling methods need to be utilized in some areas.



The junction structure of two traffic tunnel need to be constructed underground.

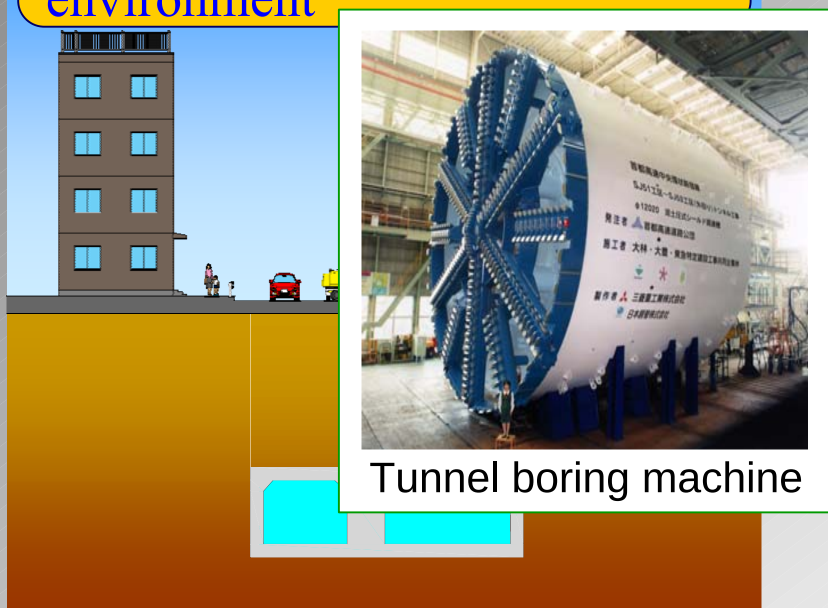


Twin Arch Junction method is proposed to built underground intersection of expressways.

Construction method

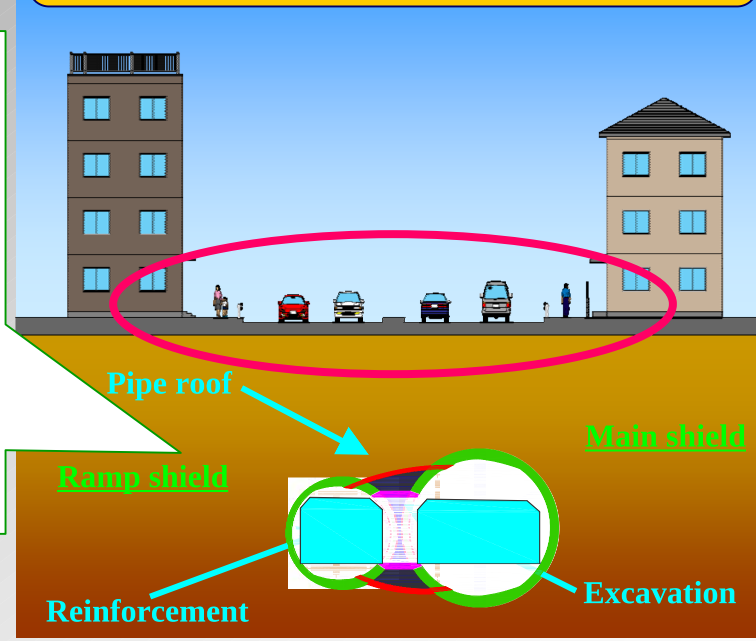
Conventional method (Open cut method)

Long construction period
Ill-Effects on the surface environment



Twin Arch Junction Beams

No ill-effects on the surface environment



Restoration

inside construction.

Conventional Tunneling in Urban Area

Conclusions and references

Tunnelling in urban area

1. Mechanized tunnelling
   Machine cost is high
   Hard to adapt if the cross section is changed

2. Conventional Tunnelling
   Will be used under more difficult conditions

Technologies to be developed

1. Numerical analysis to evaluate ground behavior
2. Developing auxiliary methods, such as ground stabilization, ground freezing, underground water control