

# **ISTANBUL STRAIT IMMERSED TUNNEL**

## **Considerations and Strategies behind Design & Construction Requirements**

Bosphorus Rail Tunnel  
Istanbul, Turkey



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# Prime Directives

- Design-build project
- Performance based
- Fit for purpose
- Standards & Codes of Practice
  - Turkish
  - USA, British, EuroCode, Japanese

# Depth Issues

- Deepest immersed tunnel, 58 m deep
  - BART in San Francisco is 40 m deep



# Depth Issues - Limit Leakage

- Construction Care
- Watertight design: ignore waterpr'fing
- Mandatory waterproofing membrane
- Leakage below membranes
  - Use of anchoring ribs in concrete
  - Compartmentalize surface (10 m<sup>2</sup> max)



# Tunnel Type



Photo source unknown

Airport Rail Tunnel, HK,  
Concrete

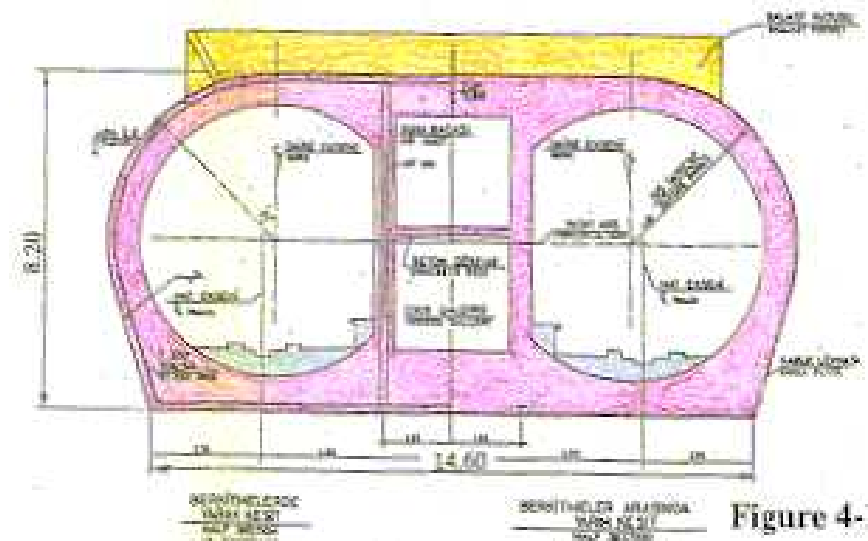
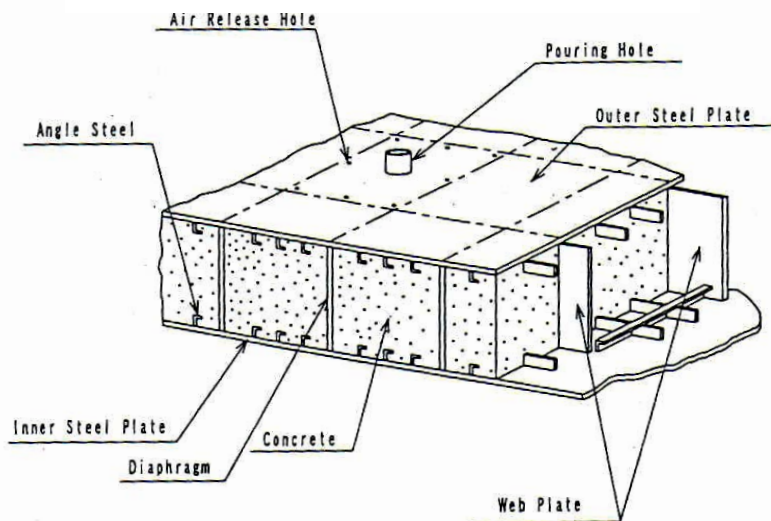


Figure 4-1 (2)

Bay Area Rapid Transit (BART), USA,  
Steel Single Shell



Naha Port & Kobe Port, Japan  
Steel Sandwich Type



Photo courtesy of Walter Grantz

Fort McHenry Tunnel, USA,  
Steel Double Shell

# Currents in Strait

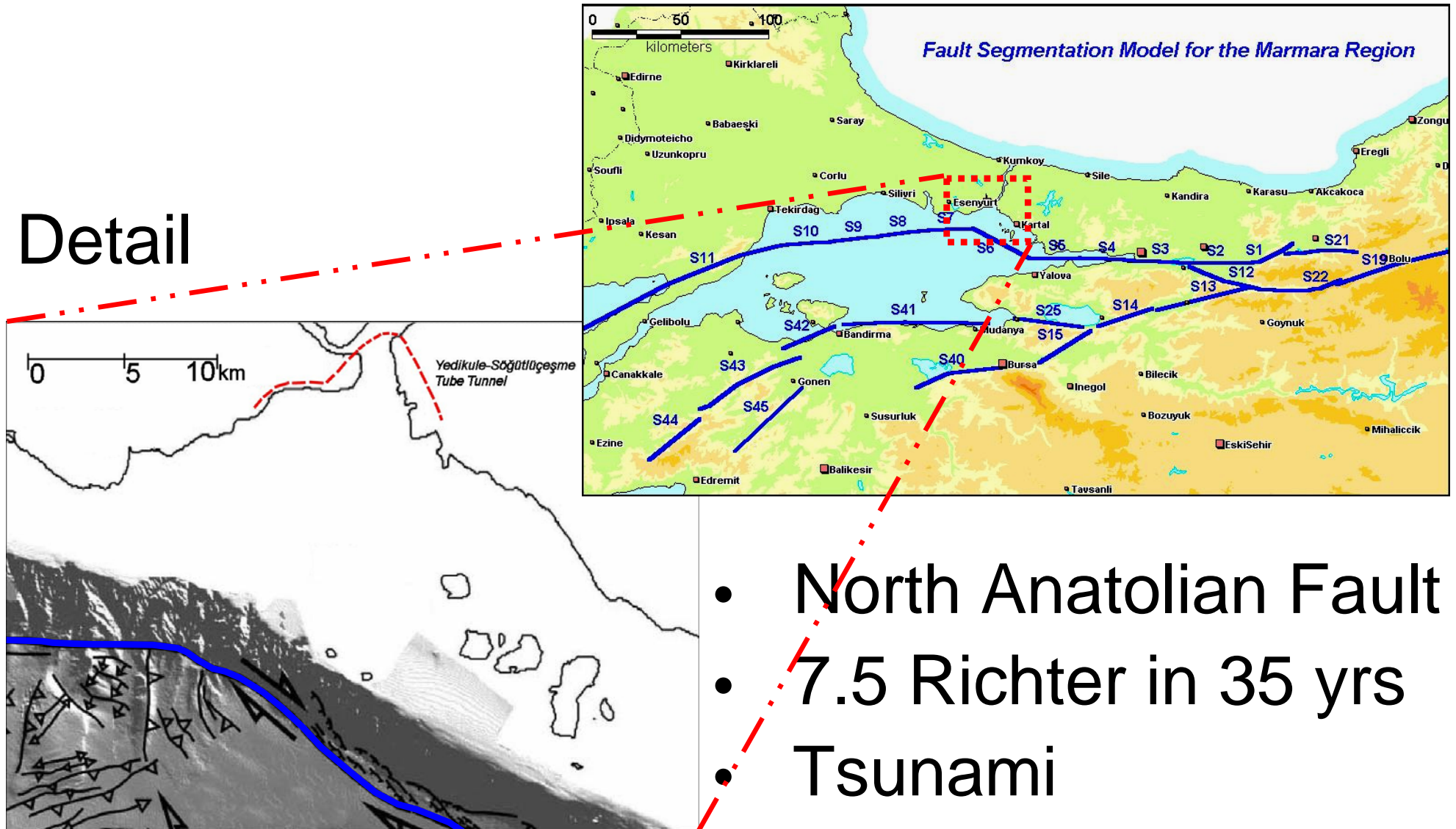
- **Currents**
  - Surface south
  - Deep north
  - Turbulent layer
- **Simulation model**
  - Calibration
- **Tunnel placing risks**
  - Model test
  - Temporary access





# Seismic Issues – Fault Nearby

# Detail



- North Anatolian Fault
- 7.5 Richter in 35 yrs
- Tsunami



# Seismic Issues – Approach

- DBE = FEE = SEE for this project
- Facility to remain operational
- Bedrock ground-motion time history
- Req'd detailed analysis methodology
- More boreholes



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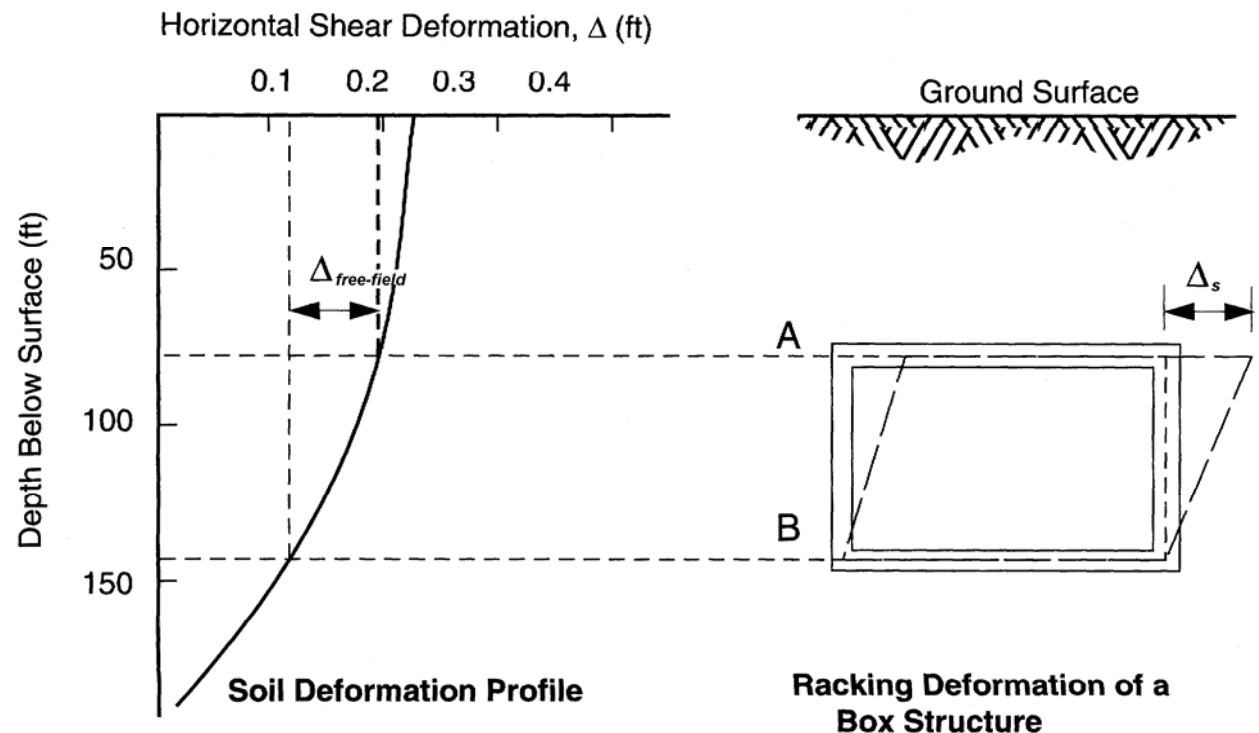
# Seismic Issues – Treatment

- Site response analysis
- Liquefaction analysis
  - Shaking loads
  - Hydrodynamic loads
- Ground improvement
- Post-earthquake loads & deformation
- Fill type

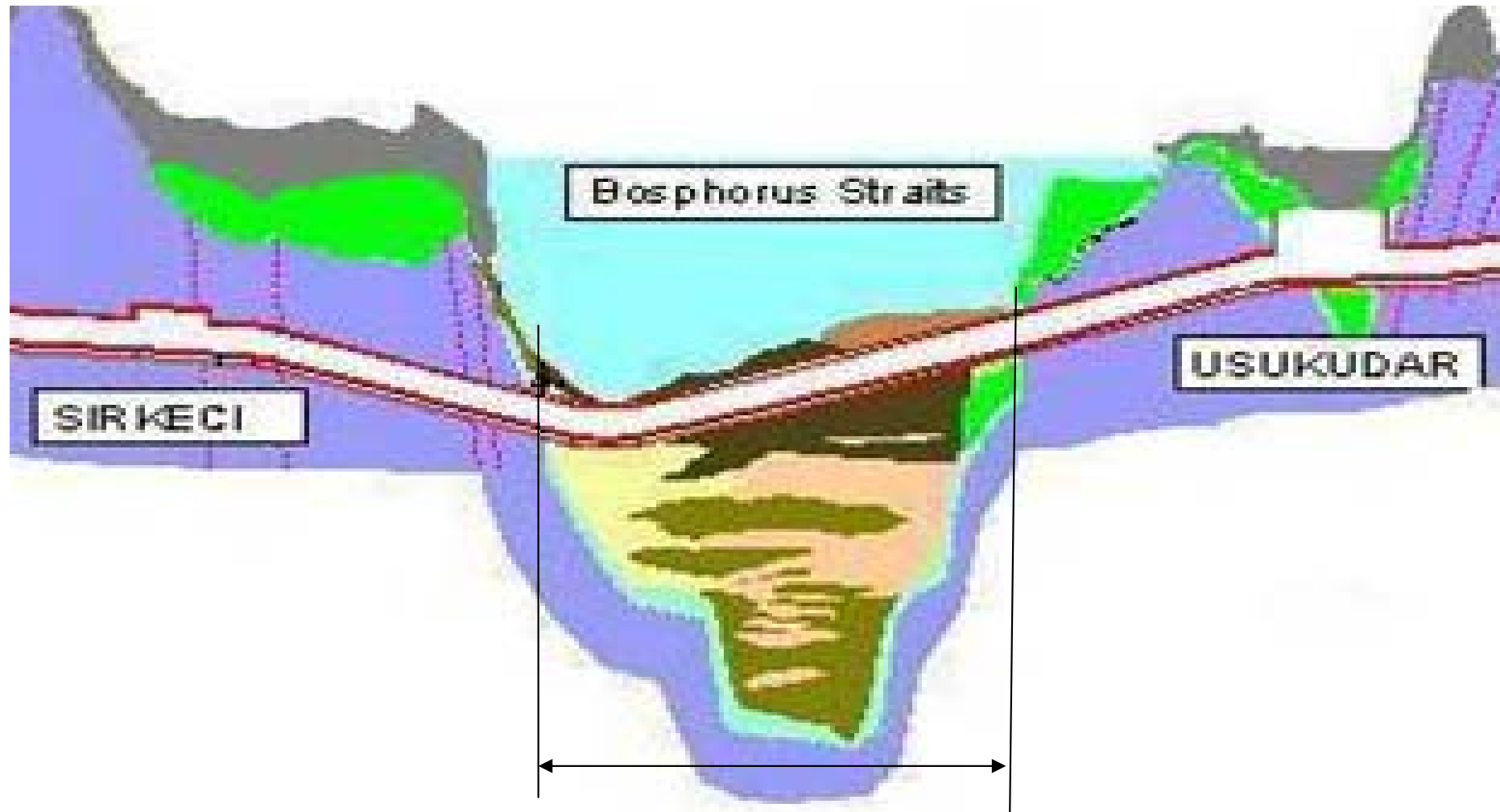


# Seismic Issues – Safety

- Longitudinal analysis
- Transverse racking analysis
- Ductility in the overload range
- Seismic joints
- Floodgates



# Geotechnical Data



Immersed Tunnel now Terminates at Rock Faces

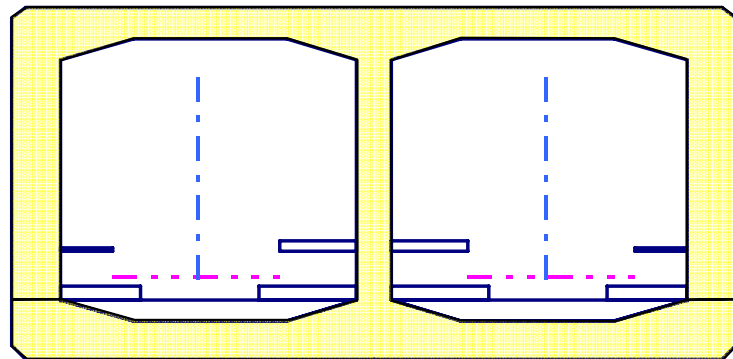
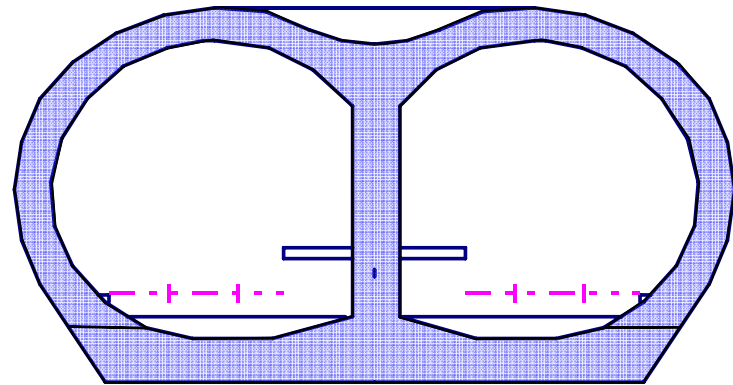
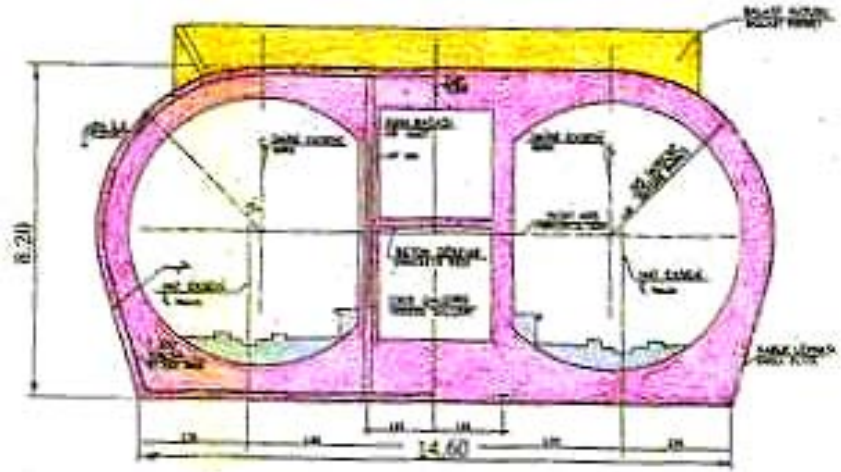


# Geotechnical Challenges

- Contractor to decide:
  - Immersed length
  - TBM to immersed connection
- Required excavation/fill analyses defined
- Long-term and post-seismic analyses
- Estimate installation level
- Internal space checks

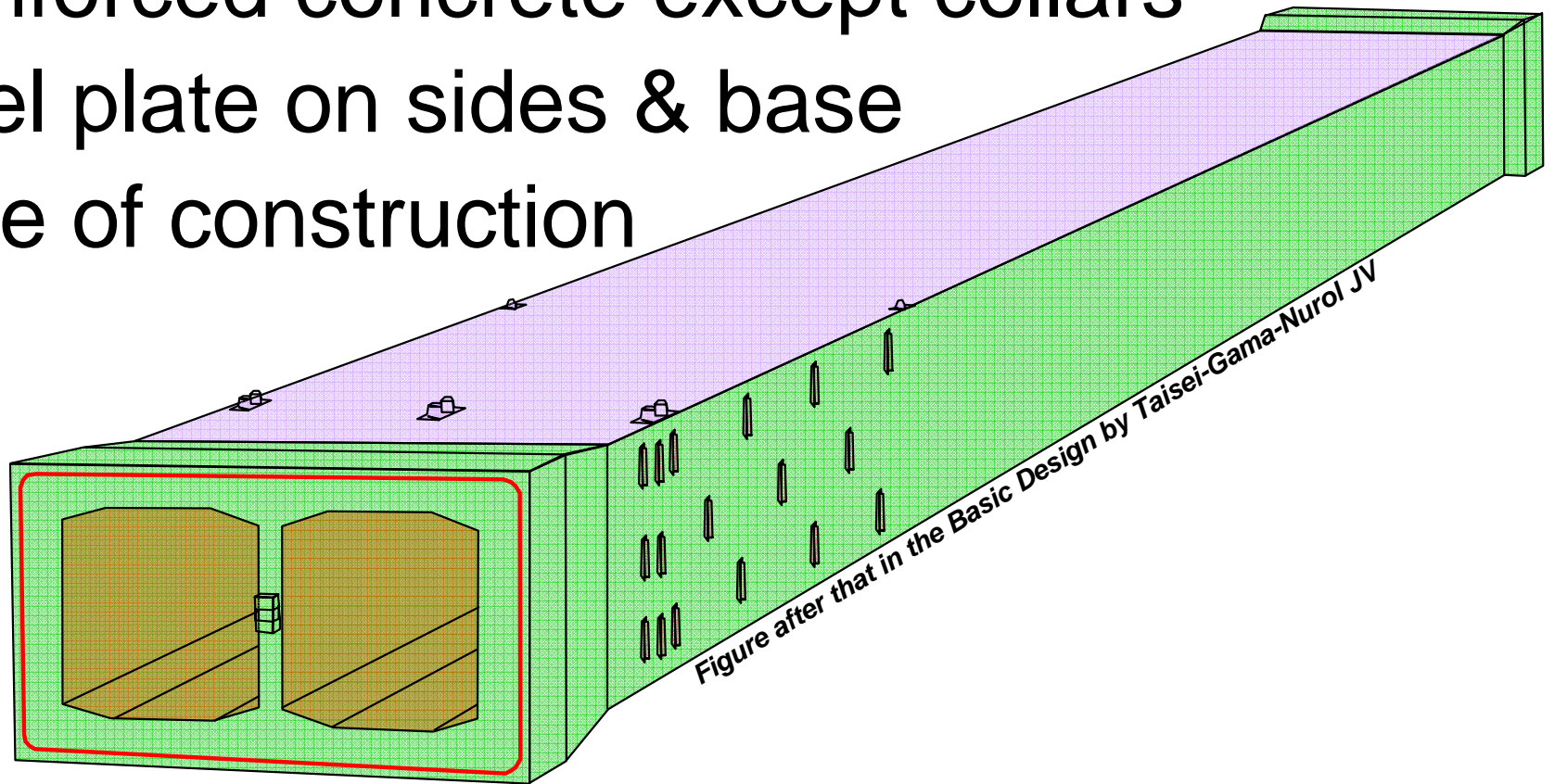
# Cross-Section

- 1985 BART-type concept
- 2002 Client concept for bid
- 2004 Contractor's Design



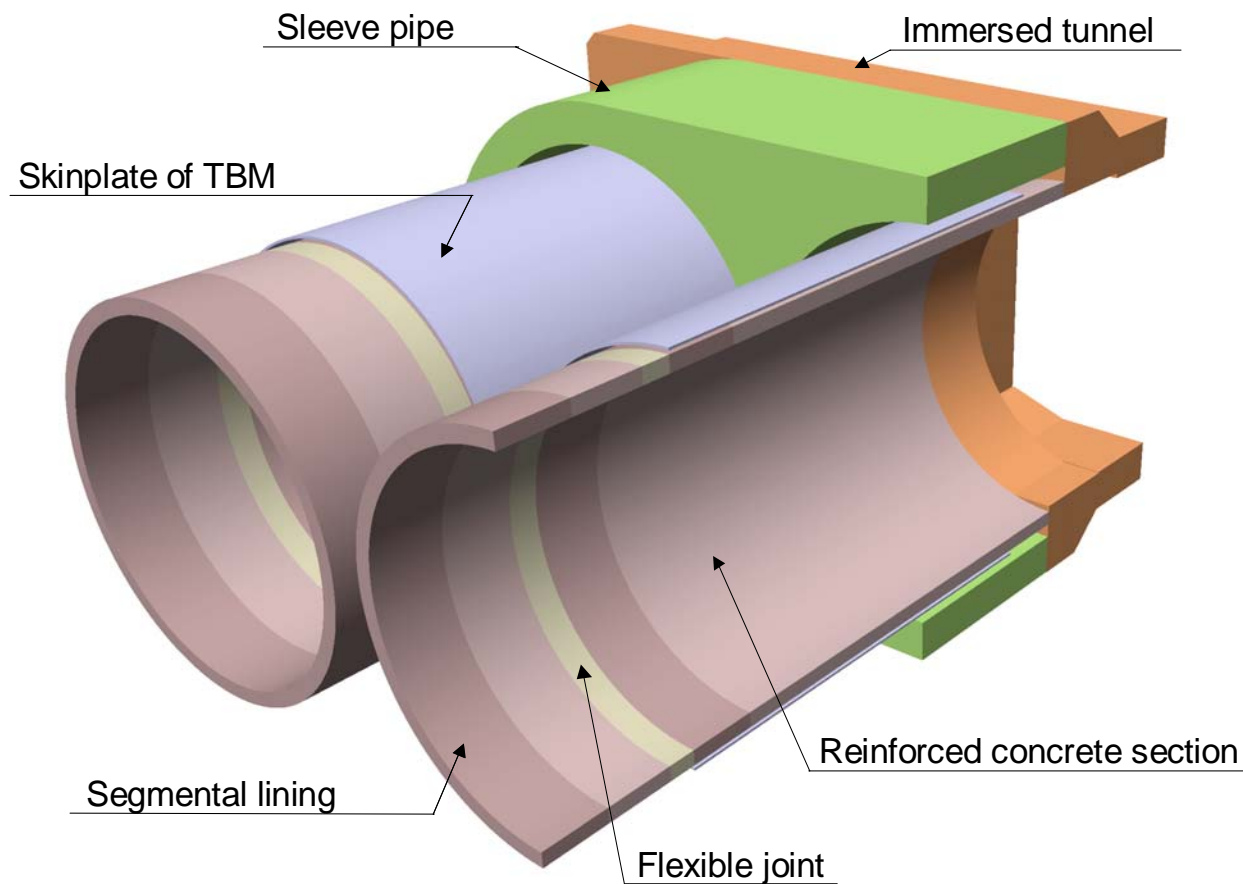
# Current TGN Design

- Construction method partially afloat
- Reinforced concrete except collars
- Steel plate on sides & base
- Ease of construction



# Unusual Features – Terminal Joints

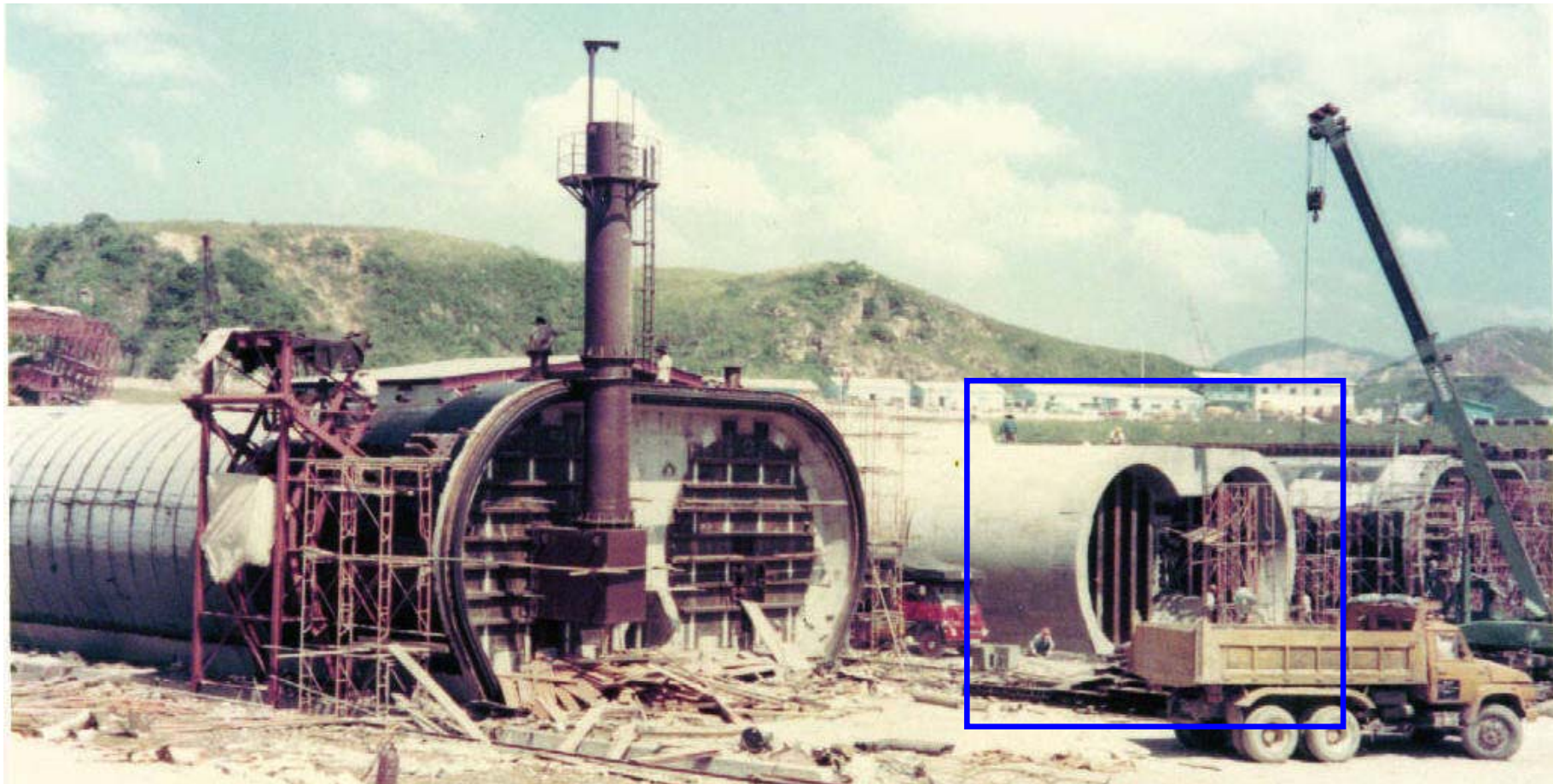
- Terminal joints in deep water
- Bored tunnels to enter immersed tunnel





# Unusual Features – Terminal Joints

- Bored tunnels to enter immersed tunnel
- Only done once before, in HK



# Construction Sequence

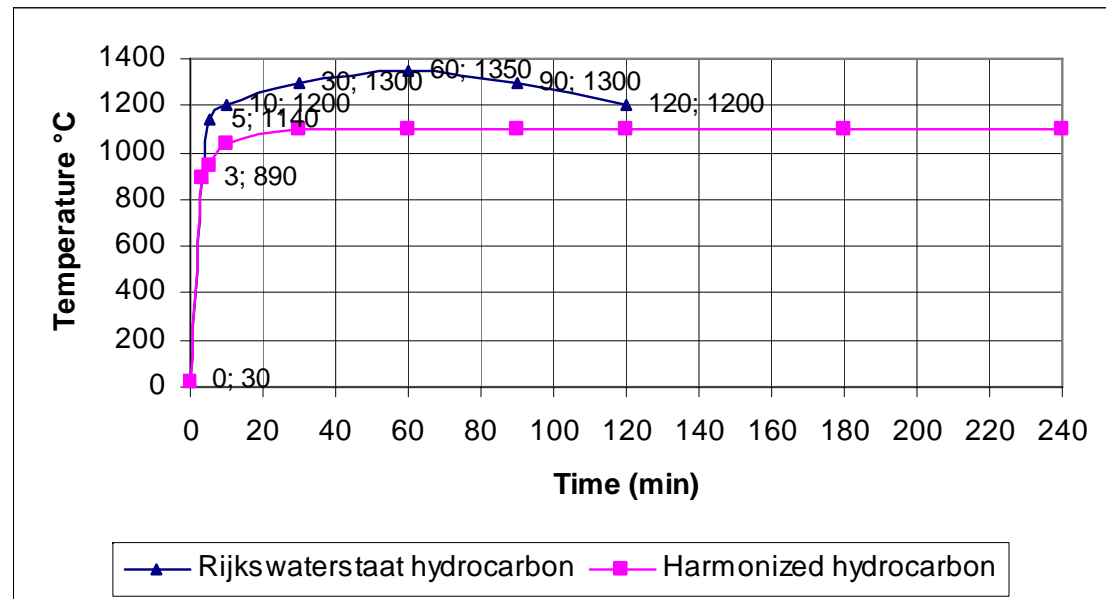
- Lay tunnel from Asian side
- Temporary access shaft by Leander's tower
- Backfill for end zones to be watertight
- Bore directly out of rock into end of immersed tunnel.

# Fire Resistance - Safety

- Provide fire insulation over ceiling & walls
- No spalling of concrete beneath insulation
- Concrete & reinforcement temperatures limited.

# Fire Protection

- Freight as well as passengers
- Two-hour 100 MW fire rating for the Rijkswaterstaat hydrocarbon curve
- Four hour rating for the harmonized curve.





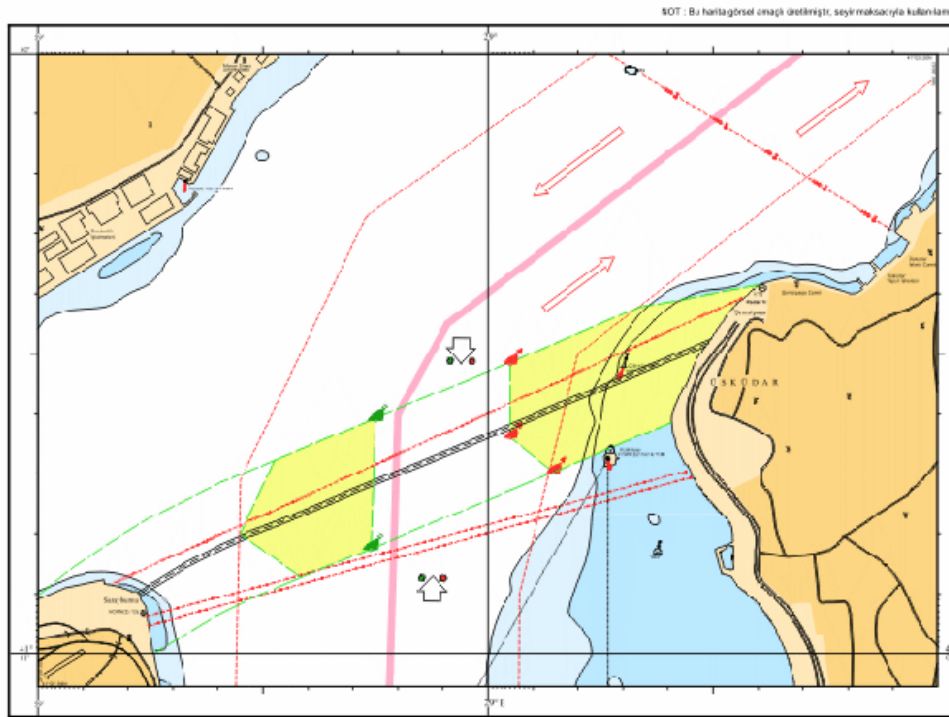
# Other Challenges

- Seabed level to remain unchanged
- Excavating & backfilling in current
  - Great depth
  - How to control location of operations
- Fish migration may limit operations
- Environmental issues
- Control of international waterway

# Notice to Mariners – Phase 4

## SOUTHERN ENTRANCE OF THE STRAIT OF ISTANBUL

Dredging and drilling works will be conducted under the frame of Marmaray Tunnel Passage Project within the area whose coordinates indicated below throughout 01 - 31 May 2005 (Phase 4). No entrance is allowed to working area.



### AREA - 1

41 01.61 N., 29 00.60 E (Coast)  
41 01.58 N., 29 00.34 E  
41 01.49 N., 29 00.05 E  
41 01.36 N., 29 00.05 E  
41 01.30 N., 29 00.15 E  
41 01.39 N., 29 00.41 E (Coast)

### AREA - 2

41 01.39 N., 28 59.75 E  
41 01.33 N., 28 59.53 E  
41 01.20 N., 28 59.45 E  
41 01.13 N., 28 59.58 E  
41 01.18 N., 28 59.74 E

STRAIT OF ISTANBUL, southern entrance is marked by lateral buoys

Green buoy location	41 01.39 N., 28 59.75 E
Green buoy location	41 01.18 N., 28 59.74 E
Red buoy location	41 01.49 N., 29 00.05 E
Red buoy location	41 01.36 N., 29 00.05 E
Red buoy location	41 01.30 N., 29 00.15 E

Note: This map is drawn for illustration purposes and cannot be used for navigation

# Safeguarding the Environment

