ISTANBUL STRAIT IMMERSED TUNNEL

Considerations and Strategies behind Design & Construction Requirements

Bosphorus Rail Tunnel
Istanbul, Turkey
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 waterproofing
- Mandatory waterproofing membrane
- Leakage below membranes
  - Use of anchoring ribs in concrete
  - Compartmentalize surface (10 m² max)
Tunnel Type

- Fort McHenry Tunnel, USA, Steel Double Shell
- Bay Area Rapid Transit (BART), USA, Steel Single Shell
- Naha Port & Kobe Port, Japan, Steel Sandwich Type
- Airport Rail Tunnel, HK, Concrete

Photos courtesy of Walter Grantz

Photo source unknown
Currents in Strait

- **Currents**
  - Surface south
  - Deep north
  - Turbulent layer
- **Simulation model**
  - Calibration
- **Tunnel placing risks**
  - Model test
  - Temporary access
Seismic Issues – Fault Nearby

- 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
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

Figure from the Basic Design by Taisei-Gama-Nurol JV
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 13 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 13 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

http://www.shodb.gov.tr/ilanlar/marmaray_ing.htm
Safeguarding the Environment