Standards and Guidelines for Design and Construction of Marine Structures against Seismic and Marine Hazards and Marmaray Project

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Marmaray

FIRST INTERNATIONAL CARIBBEAN WAVES: RISK EVALUATION OF NATURAL HAZARDS IN THE CARIBBEAN

INTRODUCTION

A new seismic design code is being enforced in Turkey,
effective September 1, 2008,
for transportation structures officially administered by
General Directorate for Construction of Railways, Harbors and Airports (RHA) of
Ministry of Transportation.

The aim of this contribution is to describe the main aspects of the RHA Seismic Code with special emphasis given to port structures.

The most important aspect of the code rests on its main approach incorporating *performance-based design*.

In view of a very limited number of seismic codes available for port structures, the new Turkish Seismic Code is expected to attract a special attention with its modern approach.

BASIC APPROACH: PERFORMANCE – BASED DESIGN

The basic design philosophy behind the code is the *performance-based design*.

As opposed to traditionally used prescriptive strength-based approach, performance-based design rests on an explicit *deformation-based approach*, where damage is *quantified* in terms of inelastic deformation demand quantities on element level under specified multi-level earthquakes.

Such *ductile* demand quantities are then evaluated against prescribed *deformation capacities* for selected *performance objectives* under each earthquake level.

In the mean time internal force quantities corresponding to *brittle* behavior modes are ensured not to exceed the specified *strength capacities*.

PERFORMANCE – BASED DESIGN PARAMETERS

As in any performance-based design code, the RHA code for port structures starts with the definition of the following performance-based design parameters:

(a) Structural classes associated with the usage, expected performance and functional importance,

(b) Seismic performance levels associated with expected damage levels,

(c) Earthquake levels associated with frequent, rare and very rare earthquakes,

(d) Seismic performance objectives under different earthquake levels.

STRUCTURAL CLASSES

SPECIAL STRUCTURES

(a) Structures to be used for rapid response and evacuation immediately after an earthquake,
(b) Structures to be used for toxic, flammable or explosive materials.

NOMINAL STRUCTURES

(a) Structures where the loss of life and property must be avoided,
(b) Structures of economic and social significance,
(c) Structures with difficult and time-consuming post-earthquake repair and retrofit needs,

SIMPLE STRUCTURES

(a) Less important structures other than those classified in Special and Nominal Structures,
(b) Structures other than those classified as Unimportant Structures.

UNIMPORTANT STRUCTURES

(a) Easily replaceable structures,
(b) Structures not causing life safety risk even extensively damaged,
(c) Temporary structures.

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SEISMIC PERFORMANCE LEVELS

MINIMUM DAMAGE (MD) PERFORMANCE LEVEL

corresponds to a state where no or a very limited damage occurs in port structures and/or in their elements. In this case, port operation continues uninterrupted or if any, service interruptions are limited to few days.

CONTROLLED DAMAGE (CD) PERFORMANCE LEVEL

corresponds to a state where non-extensive, repairable damage occurs in port structures and/or in their elements. In this case, short-term (few weeks or months) interruptions in related port operations may be expected.

EXTENSIVE DAMAGE (ED) PERFORMANCE LEVEL

corresponds to a state where extensive damage occurs in port structures and/or in their elements. In this case, long-term interruptions or even closures in related port operations may be expected.

STATE OF COLLAPSE (CS)

corresponds to the collapse state in port structures and/or in their elements. Related port operation is terminated.

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EARTHQUAKE LEVELS

(E1) Earthquake Level

represents relatively frequent but low-intensity earthquake ground motions with a high probability to occur during the service life of port structures. The probability of exceedance of (E1) level earthquake in 50 years is 50%, which corresponds to a return period of 72 years.

(E2) Earthquake Level

represents the infrequent and high-intensity earthquake ground motions with a low probability to occur during the service life of port structures. The probability of exceedance of (E2) level earthquake in 50 years is 10%, which corresponds to a return period of 475 years.

(E3) Earthquake Level

represents the highest intensity, very infrequent earthquake ground motions that port structures within the scope of the code may be subjected to. The probability of exceedance of (E3) level earthquake in 50 years is 2%, which corresponds to a return period of 2475 years.

MINIMUM PERFORMANCE OBJECTIVES

Port Structure Class	*(E1) Earthquake Level*	*(E2) Earthquake Level*	*(E3) Earthquake Level*
Special	–	MD	CD
Nominal	MD	CD	(ED)*
Simple	CD	(ED)*	–
Unimportant	(ED)*	(CS)*	–

* *Implied objectives* not requiring design verification.

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ANALYSIS AND DESIGN PROCEDURES

Being a performance-based code, the new seismic code for port structures mainly rests on a *deformation-based design (DBD)* approach, which requires the implementation of nonlinear seismic analysis procedures.

However, linear analysis procedures within the framework of traditional *strength-based design (SBD)* are also allowed for the verification of *Minimum Damage (MD) Performance Objective* where structural behavior is at or near the elastic limits.
Linear procedures are further allowed for the verification of *Controlled Damage (CD) Performance Objective* with relatively conservative design parameters.

APPLICABLE DESIGN APPROACHES TO PORT STRUCTURES

Port Structure Class	(E1) Earthquake Level	(E2) Earthquake Level	(E3) Earthquake Level
Special	–	SBD / DBD	DBD
Nominal	SBD	SBD / DBD	–
Simple	SBD	–	–
Unimportant	–	–	–

NEW TURKISH SEISMIC DESIGN CODE FOR PORT STRUCTURES: A PERFORMANCE-BASED APPROACH

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INTRODUCTION

A seismic design code has been published in the Official Gazette of Turkish Republic on 18 August 2007 which will be applicable to transportation structures administered by the General Directorate for Construction of Railways, Harbors and Airports (RHA) of Ministry of Transportation. The important aspect of the code rests on its main approach incorporating "performance-based design" (PIANC, 1997).

CLASSIFICATION OF PORT STRUCTURES

First, port structures have been classified with respect to their anticipated seismic performance, usage and functional importance leading to classes of "special", "nominal", "simple" and "unimportant" structures.

PERFORMANCE LEVELS

Standard performance levels for port structures have been specified in terms of different damage levels:

a) Minimum Damage (MD) Level
b) Controlled Damage (CD) Level
c) Extensive Damage (ED) Level
d) Collapse State (CS)

SEISMIC GROUND MOTION LEVELS

Three levels of design earthquakes E1, E2 and E3 have been specified with return periods of 72, 475 and 2475 years, corresponding to 50%, 10% and 2% probability of exceedance in 50 years, respectively. Spectral accelerations at 0.2 second and 1.0 second have been given for all coastal regions in the country.

MINIMUM PERFORMANCE OBJECTIVES

Minimum performance objectives are specified for each class of structure under different earthquake levels as shown in Table 1.

Table 1. Minimum performance objectives

Sructure Class	(E1) Earthquake Level	(E2) Earthquake Level	(E3) Earthquake Level
Special	-	MD	CD
Nominal	MD	CD	ED*
Simple	CD	ED*	-
Unimpor	ED*	CS*	-

"Implied objectives" not requiring verification.

Table 1. Use of Design Methods objectives

Sructure Class	(E1) Earthquake Level	(E2) Earthquake Level	(E3) Earthquake Level
Special	-	SBD/DBD	DBD
Nominal	SBD	DBD	-
Simple	SBD	-	-
Unimpor	-	-	-

Table 3. Seismic Load Reduction Factors

Pile Arrangement	Performance Level MD	CD
Vertical Piles	1.5	2.5
Batter Piles	1.0	1.5

New Turkish Code for Coastal and Port Structures

Contents;

1-Earthquake code for coastal and port structures
2-Coastal and Port Structure Design Code
3-Geotechnical Code
4-Material, Construction, Control and Maintanence Code

DESIGN METHODS

Two different design methods have been specified, namely, Strength-Based Design (SBD) Method and Deformation-Based Design (DBD) Method. As an example, Table 2 shows the use of such methods in piled pier and wharf structures.

Strength-Based Design (SBD) Method based on linear analysis with reduced seismic loads is generally employed to verify the Minimum Damage (MD) performance objective. As an example, Seismic Load Reduction Factors (R) are given in Table 3 for piled pier and wharf structures.

Deformation-Based Design (DBD) Method based on nonlinear analysis is essentially used in "nominal" and "special" structures to verify the Controlled Damage (CD) performance objective. Recommended nonlinear analysis procedures include response-history analysis in time domain as well as single-mode and multi-mode pushover analyses. In piled structures, soil is modeled with nonlinear p-y, t-z and P-Z springs. Inelastic deformation demands obtained from nonlinear analysis are verified against the corresponding capacities defined for various performance objectives. Strain capacities are given in Table 4 for pile sections.

REFERENCE

PIANC(1997), Seismic Design Guidelines for Port Structures, A.A.Balkema Publishers.

Table 4. Strain capacities for piles

Strain	Performance Level MD	CD[2]
Conc. Strain in RC Piles	0.004	0.020/008
Rebar Strain in RC Piles	0.010	0.040/0.016
PS Strain in RC Piles	0.005[1]	0.040/0.016
Strain in Steel Piles	0.008	0.030/0.012

[1]Strain increment due to earthquake
[2]Figures on right for underground structures

FIRST INTERNATIONAL CARIBBEAN WAVES: RISK EVALUATION OF NATURAL HAZARDS IN THE CARIBBEAN

- Coastal and Port Structure Design Code
- Geotechnical Code
- Material, Construction, Control and Maintanenence Code

Marmaray Project

Marmaray

Employer's Representative

- Pacific Consultants International
- Yüksel Proje Uluslararası A.Ş.
- Japan Railway Technical Services
- Oriental Consultants Co. Ltd.
- Subcontractors
  - Parsons Brinckerhoff International Inc.
  - Terzibaşıoğlu Müşavir Mühendislik Ltd.
  - Sial Yerbilimleri Etüd ve Müşavirlik Ltd.

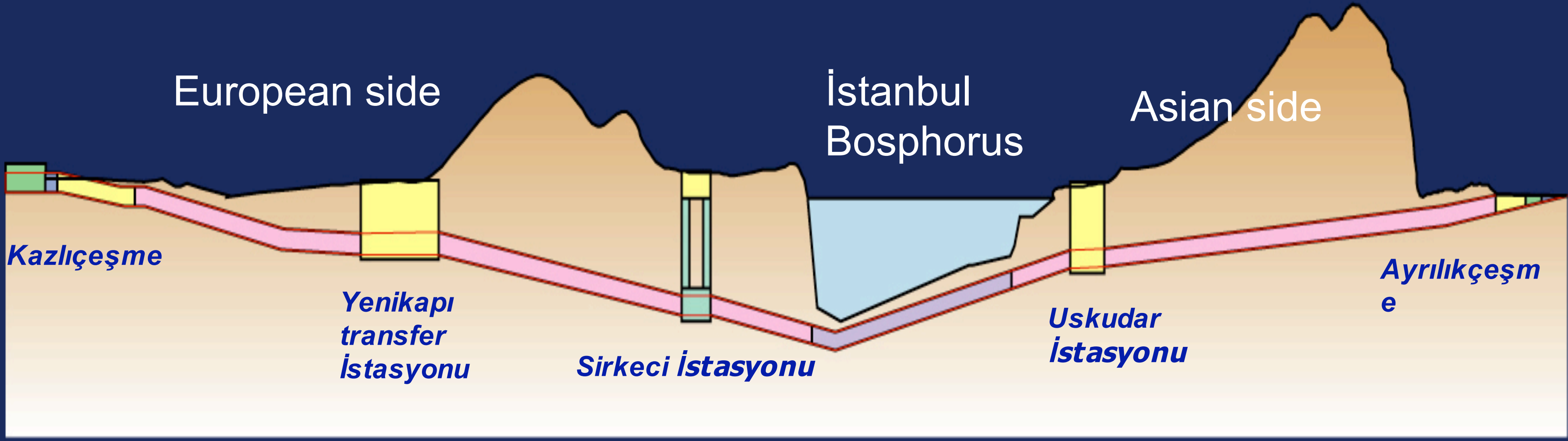
3 separate Contracts

- The Bosphorus Crossing (BC1)
  - Immersed Tube Tunnel under the Bosphorus
  - Bored Tunnels under the City on both sides
  - 4 new Stations (Kazliçeşme, Yenikapı, Sirkeci and Uskudar)
- The Upgrading of the Commuter Rail (CR1)
  - A third track (for IC and freight) on surface and full upgrading of existing tracks and Stations
  - New Signaling, Communication, Fare collection, Operations Control Centre etc.
- New Rolling Stock (CR2)
  - 44 number of 10 car trains

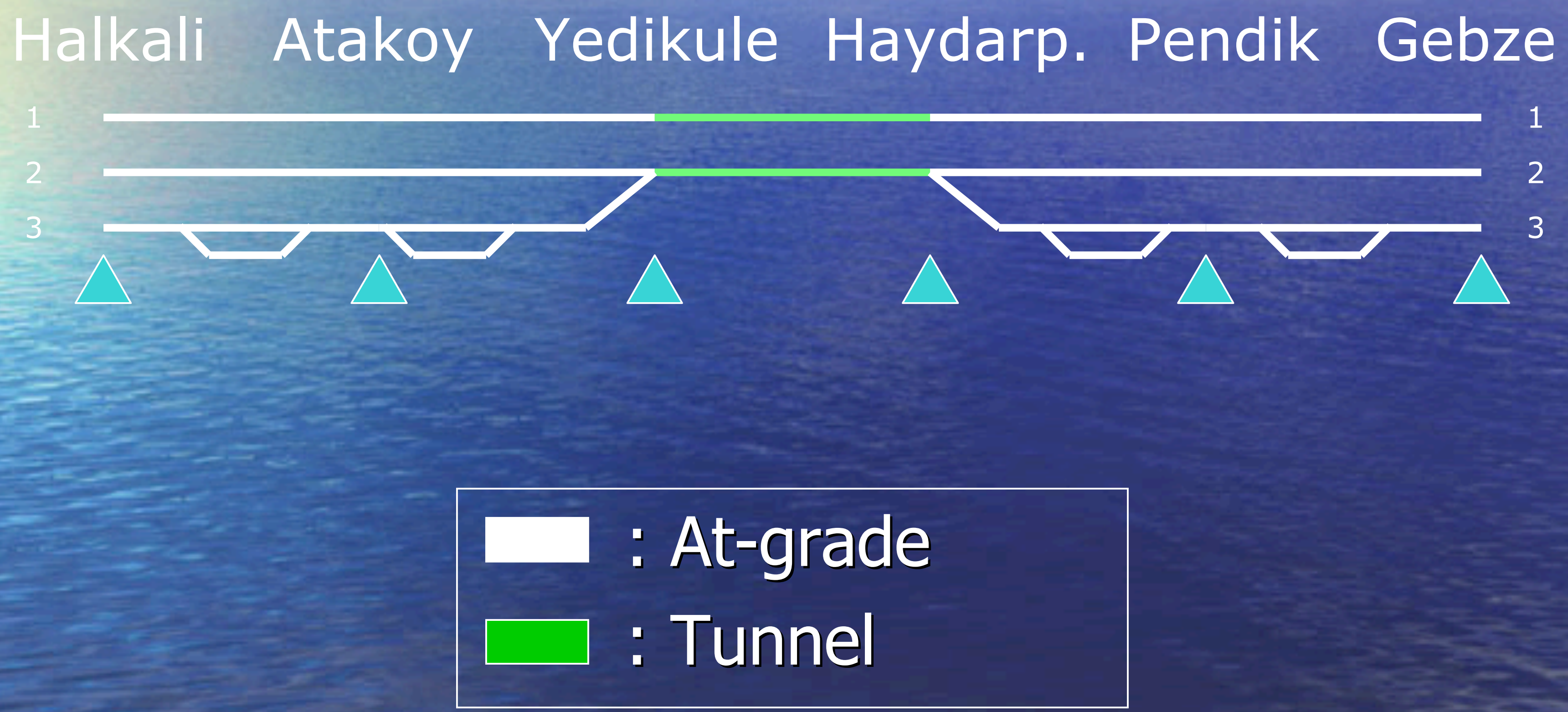
The Marmaray Project

- Total length of Commuter Rail is app. 77 km:
  - At grade, European side 19.6 km
  - At grade, Asian side 43.4 km
  - Bored tunnels 12.2 km
  - Immersed tube tunnel 1.4 km

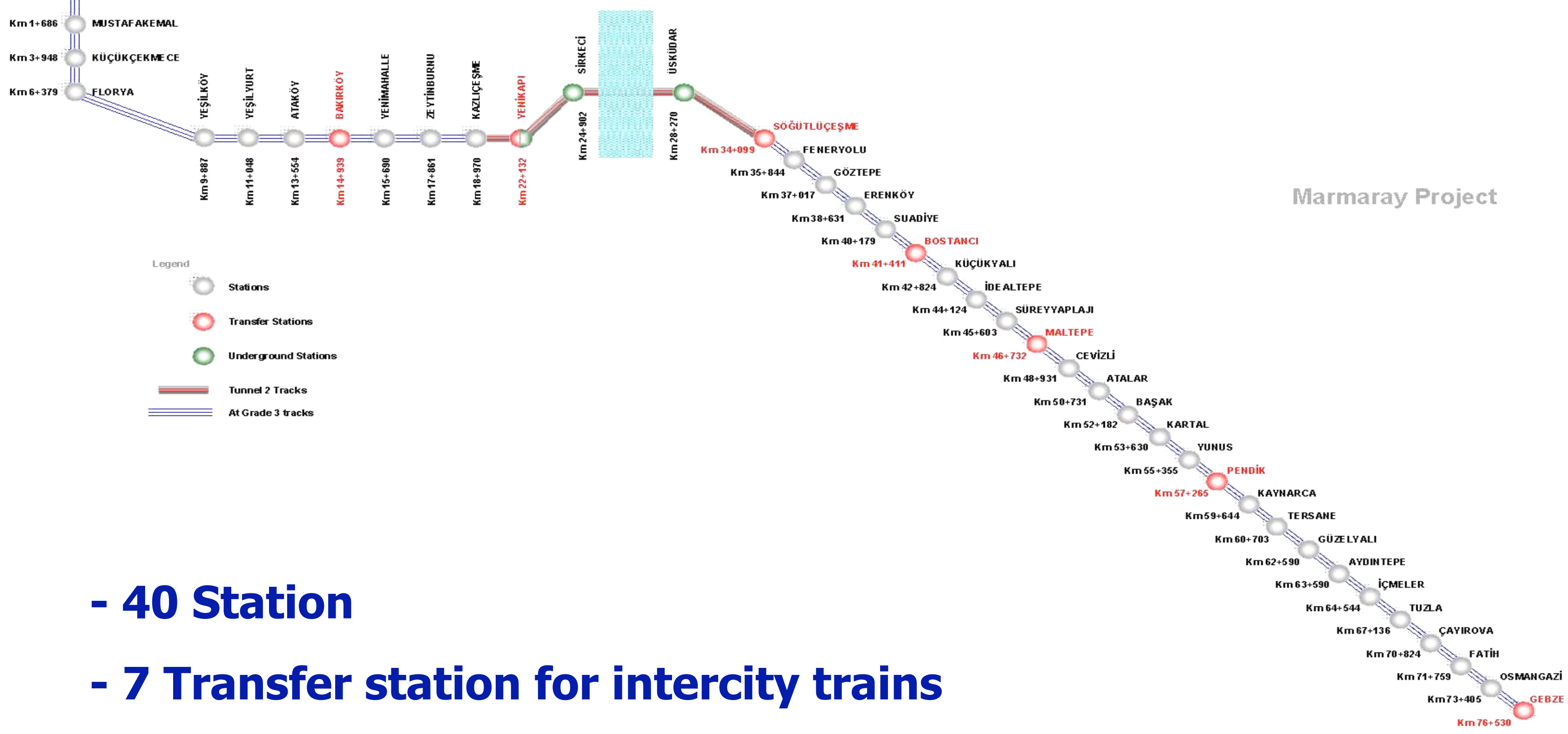
BC1 ALINGMENT PROFILE



Schematical Alinment Plan



Marmaray Stations



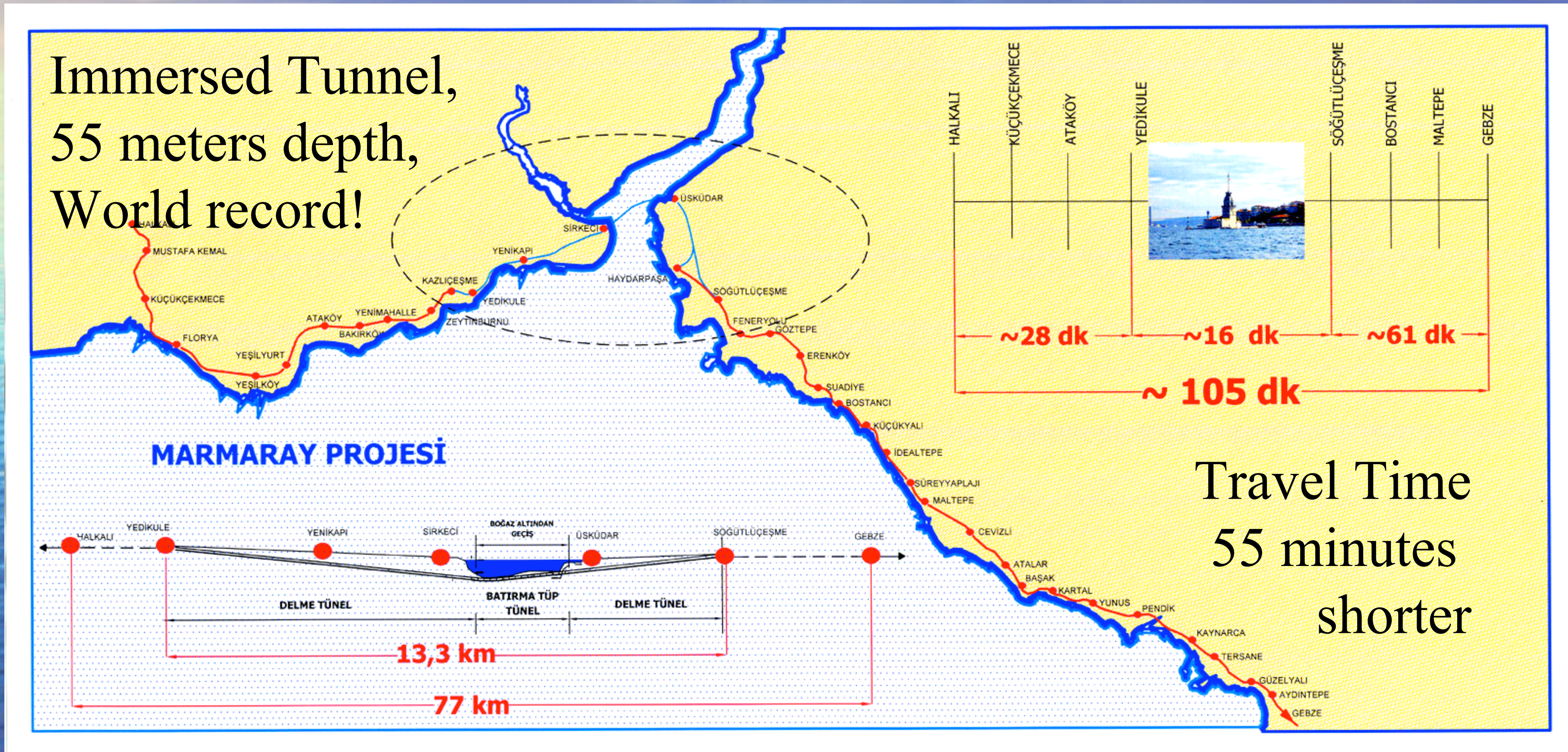
- 40 Station

- 7 Transfer station for intercity trains

The Benefits of the Project

- The Project will:
  - Create long-term solution to transportation problems of Istanbul
  - Have a capacity of 75.000 passengers per hour per direction
  - Reduce impacts of Car Traffic in the old City
  - Reduce congestion on the existing bridges
  - Connect the Railway from Europe to Asia and visa versa
  - Decrease pollution in Istanbul, decrease CO_2 release
  - Decrease travel time for more than 1 million people every day

Alignment and Travel Time



Travel time between Gebze & Halkalı will be 55 min shorter.

The travel time between Üsküdar and Sirkeci will only be 4 minutes.

Employer's Requirements

- Design & Build type of Contract
- Fitness for purpose (functional requirements)
- Minimum requirements
  - Design
  - Materials
  - Workmanship
- "Balanced" requirements, room for variations

Marmaray Project
Total Costs, Full Project, 1999 Estimate

Topic	**Million US$**
Bosphorus Crossing and CR1 Civil	1.100
Commuter Rail, Rolling St. and E&M	1.500
Grand Total, approximately	**2.600**

The Bosphorus Crossing (BC1)

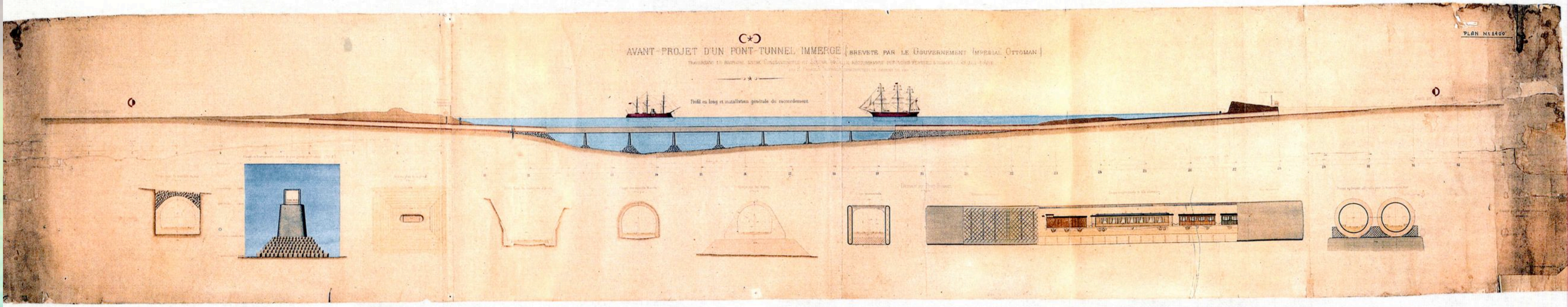
The Contractor

- Taisei Corporation, Lead Partner, Japan
- Gama, Turkey
- Nurol Insaat, Turkey

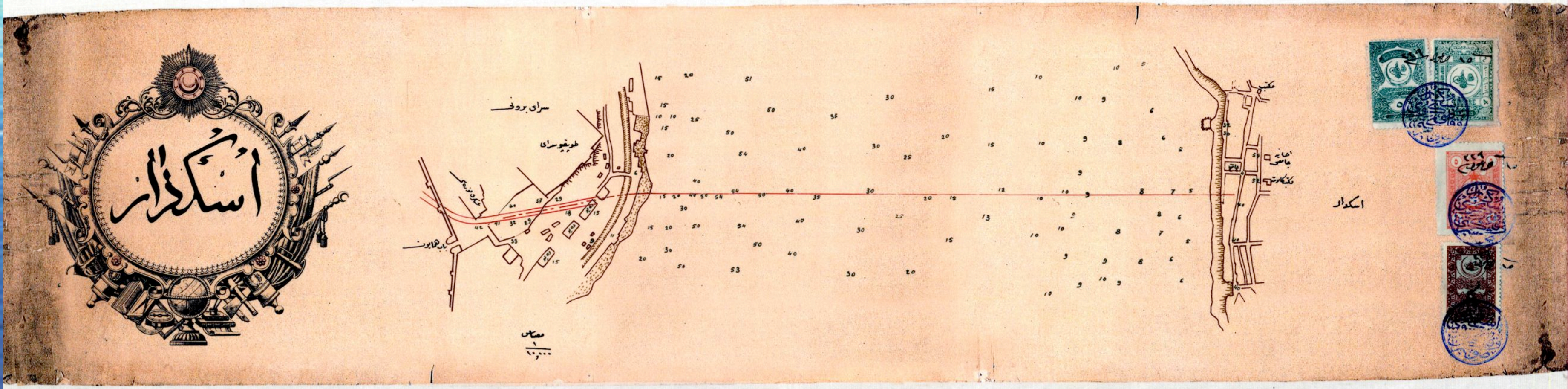
Contract Price: 823 million USD

Commencement date: 27th August 2004

The Background (or history)



1860 tarihli orijinal Tüp Geçit Projesi Planı



Orijinali Üsküdar Belediyesi'nde bulunan Osmanlı Dönemi Tüp Geçit Proje Detayı

Year 1860 Engineer S.Preault **Sarayburnu - Üsküdar**

Marmaray Project

A dream of

150 years

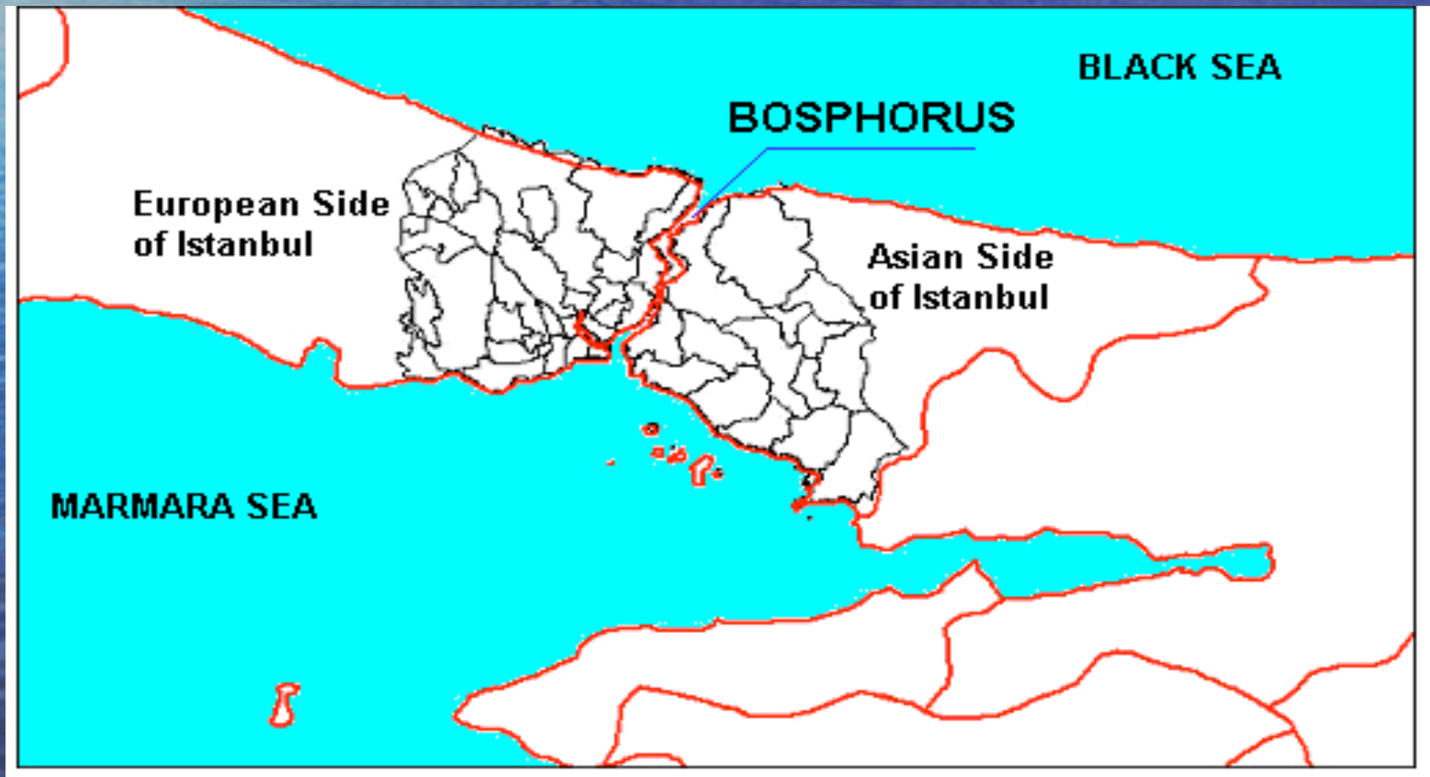
Year 2004

Sarayburnu - Üsküdar

Challenging Project

- Deepest Immersed Tunnel
- Heavy Sea Traffic Area
- Stratified Currents up to 5 knots
- Earthquake Zone

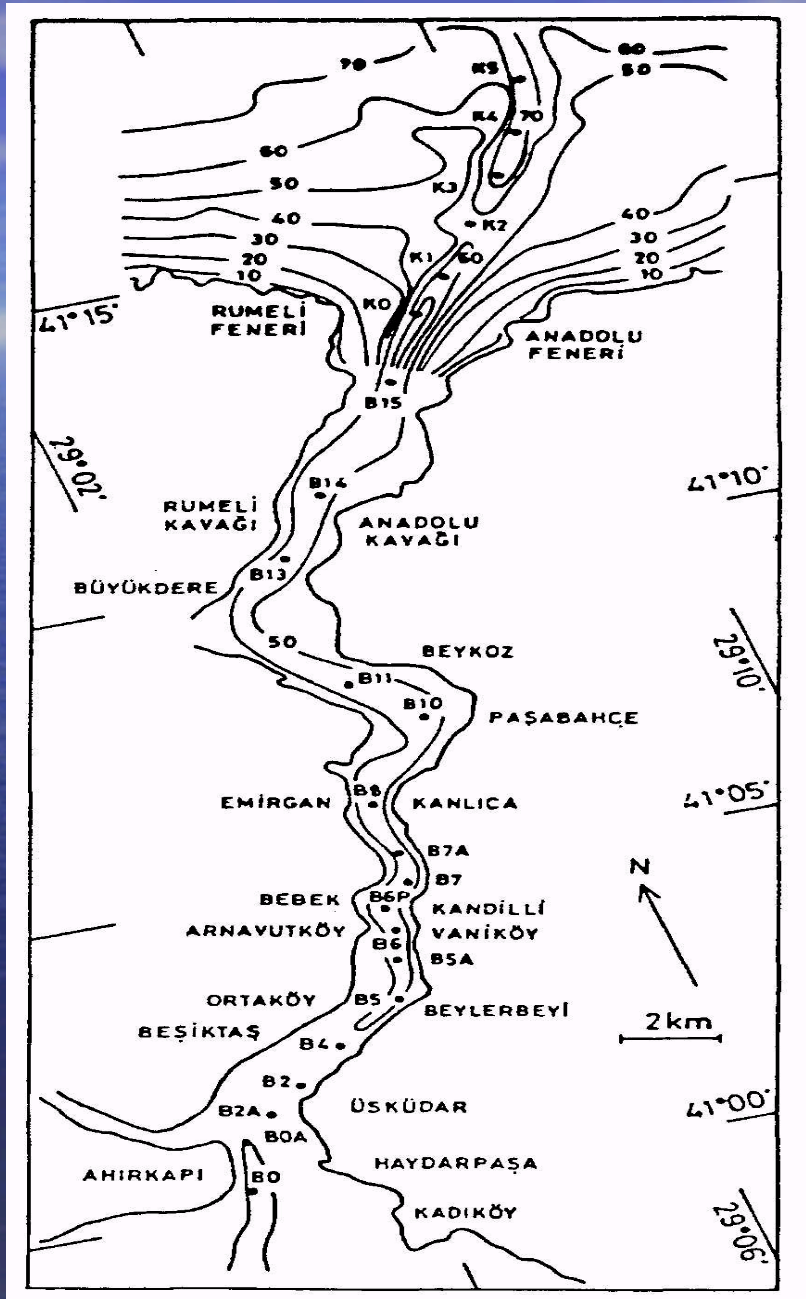
- The Bosphorus Strait is a pathway between Marmara and Black seas.
- Its width varies between 0.7 and 3.5 km with average value of 1.3 km at the surface.
- The depth varies in the range of 30 and 100 m.



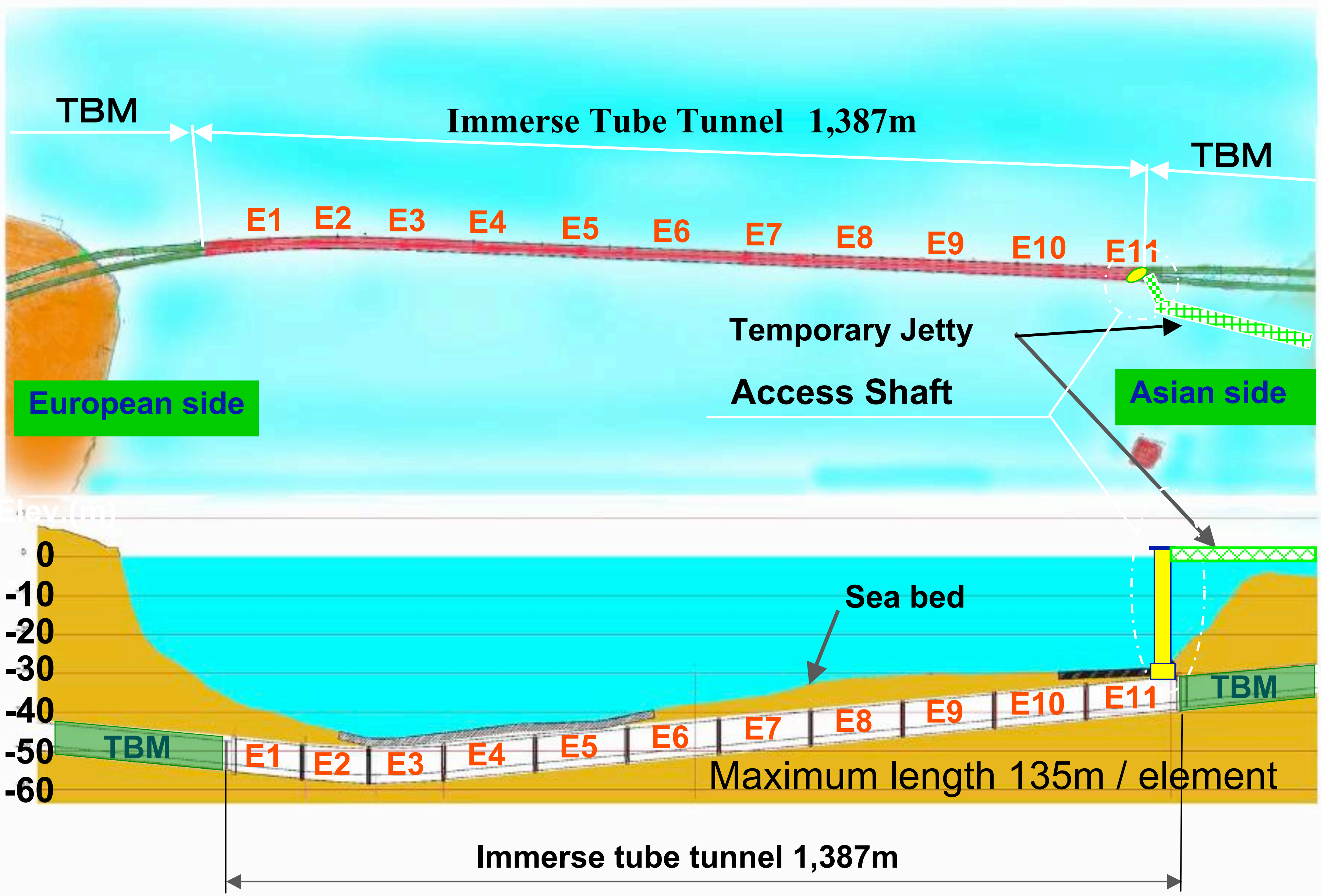
- The flow in Bosphorus Strait is a strongly two stratified two-layer system:
- (1) an upper-level current that flows south from the Black Sea to the Sea of Marmara; and
- (2) a lower-level current that flows north from the Sea of Marmara to the Black Sea.

- The stratified current is controlled by mainly two reasons which are density and water depth differences.

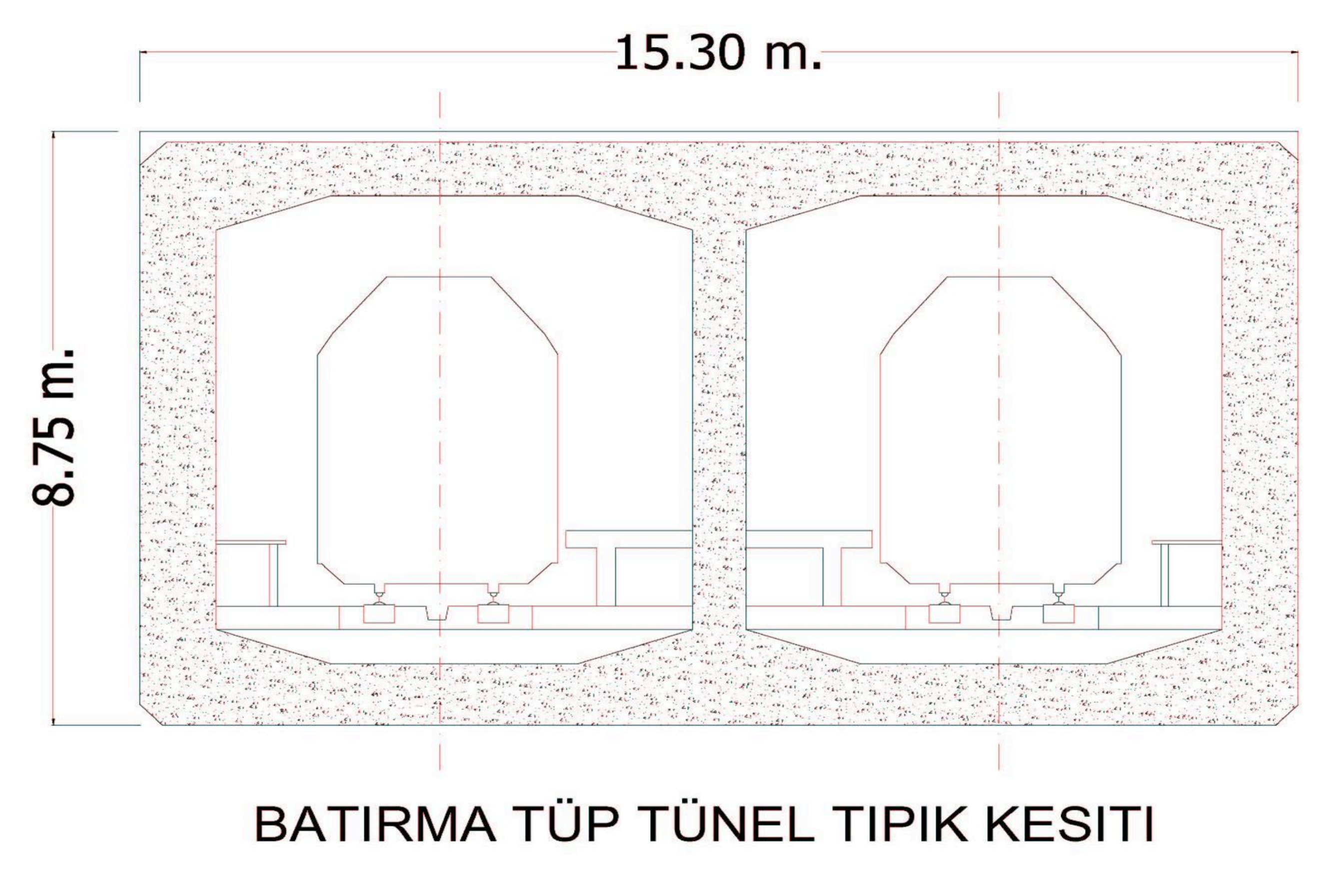
- The Bosphorus Strait has significant variations in width and depth along its length.
- Two sills located near the both entrance regions.
- The sills inlfuences the flow characteristics within the Bosphorus.



Immersed Tube Tunnel Plan&Profile



Typical Cross-section of IMT



Lengths ;

E1~E2 ; L = 98.5 m.

E3 ; L = 110 m.

E4~E11 ; L = 135 m.

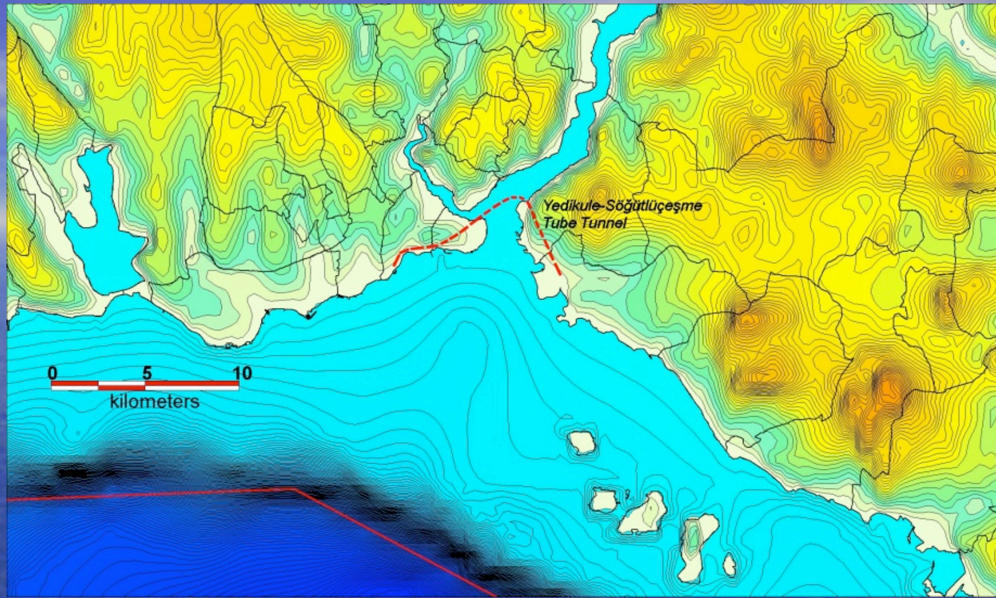
Design

Loads

- Dead and Live Loads
- Train load (UIC-S1950)
- Hydrostatic loads
- Current effect
- Ground Loads
- Differential Settlement
- Temperature Effects
- Fire
- Explosion Load
- Train Derailment Load
- Falling and Dragging Anchors
- Sunken Ship Effect
- Seismic Loads.

Seismic Design Performance Requirements for Bosphorus Crossing

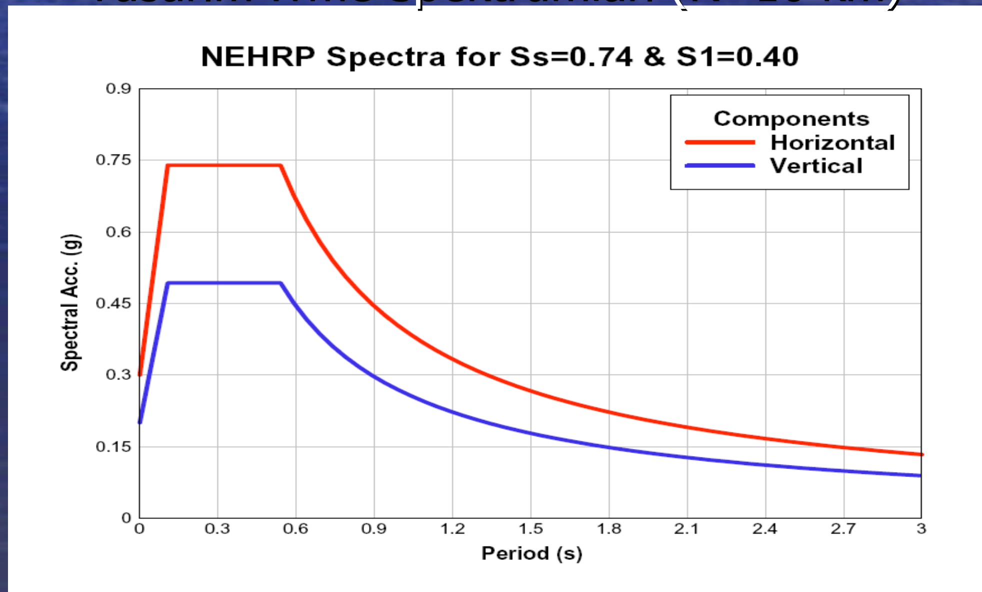
Design Basis Earthquake (Moment Magnitude : Mw=7.5)



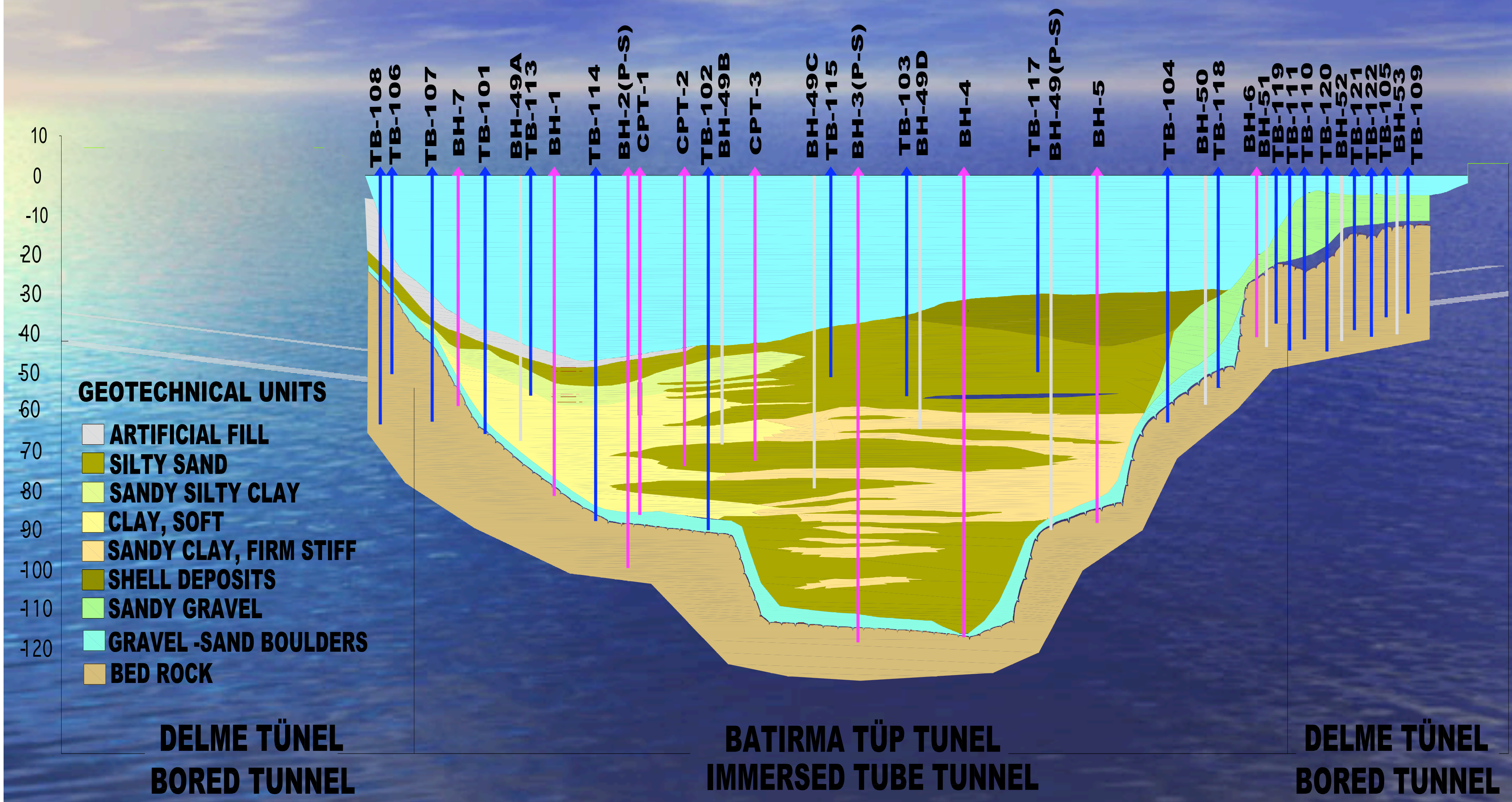
<u>Performance Criteria ;</u>

- No Risk to Life Safety
- Minimum Risk of Losing Functionality (normal operation can be quickly resumed)
- Minor and Easily Repairable Damage to Structural Elements
- Minimum inelastic Deformations
- Immersed Tunnel and Joints Remain Watertight

Tasarım İvme Spektrumları (R=16 km)

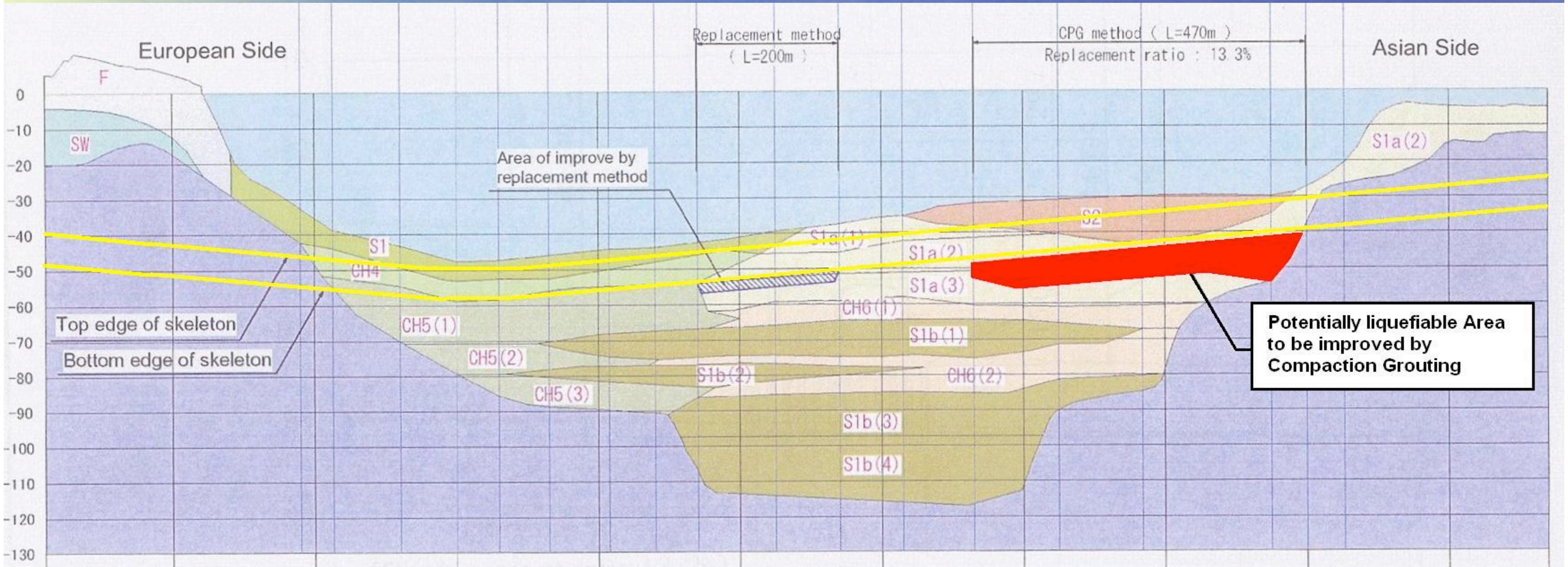


Geological Profile of the Strait



49 Boreholes are drilled in the strait in 3 campaigns

Ground Improvement Works

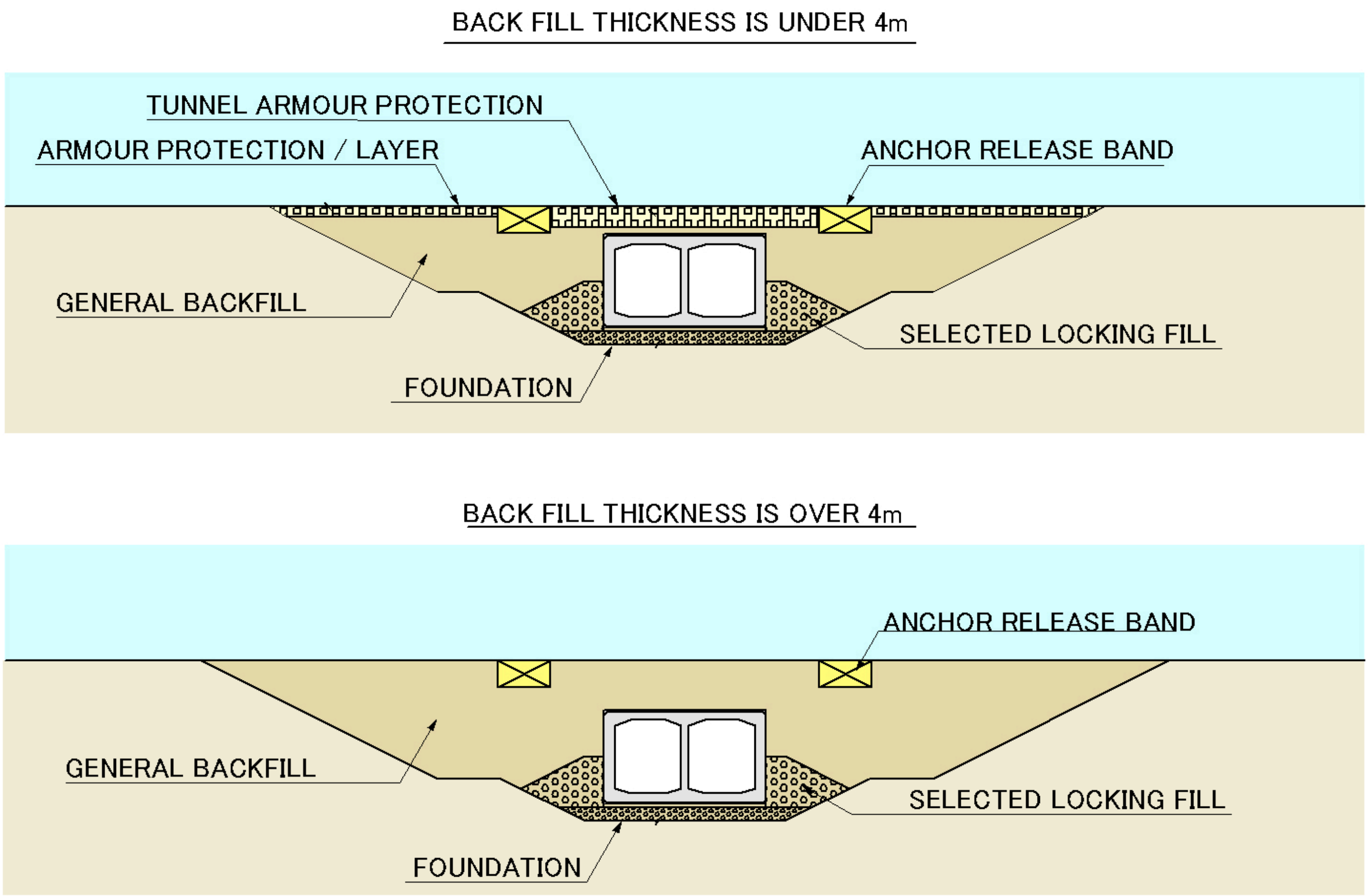


Treatment area: 471 x 20.5 m1 Depth: 4 – 10 m under tunnel

Dredging Works


ŞİŞHANE
ÜSKÜDAR
UNKAPANI
SİRKECİ
YENİKAPI

Dredging Works

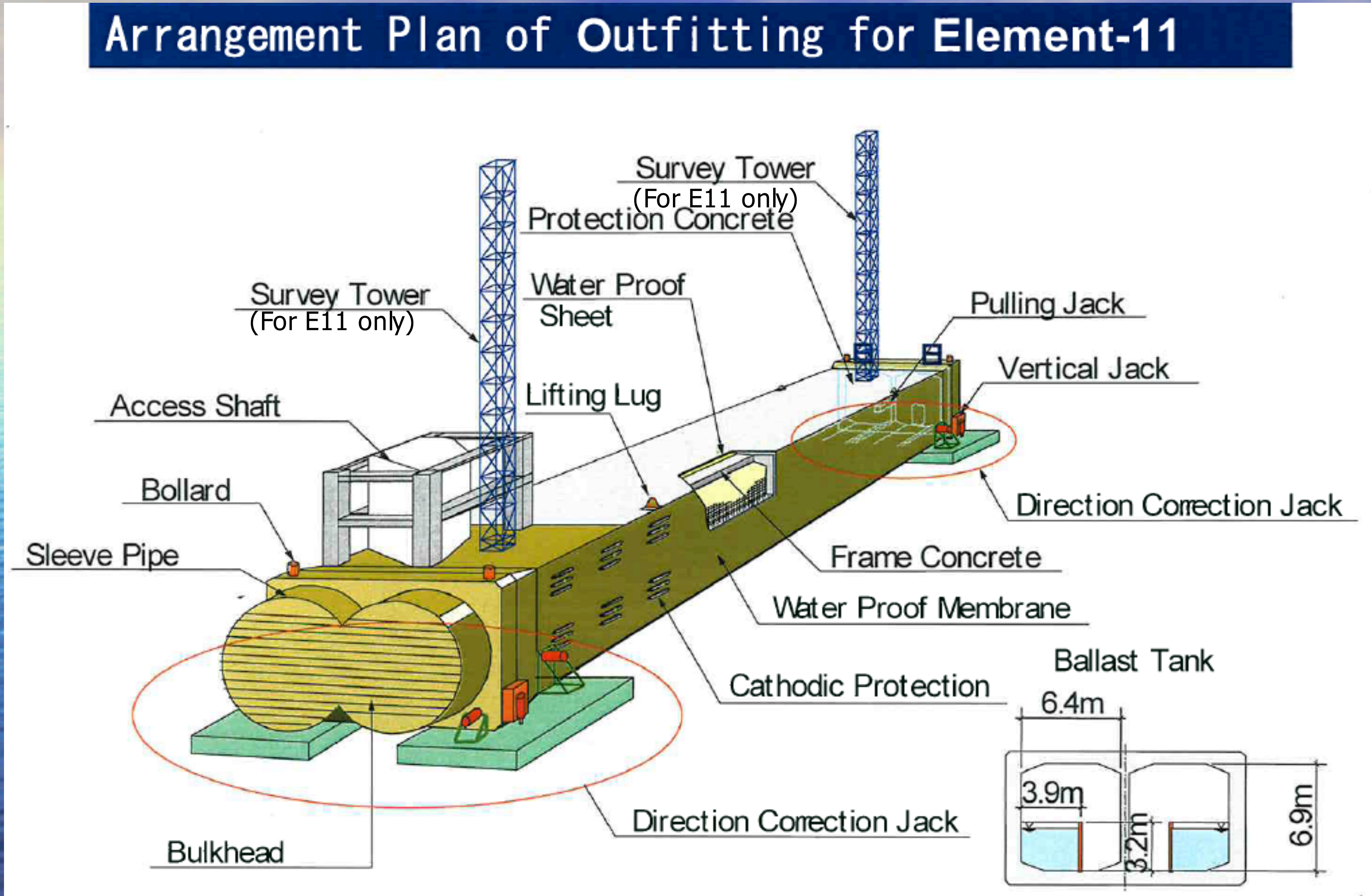


Contaminated soil: 120.000 m3 **Clean soil: 1.000.000 m3**

Stone backfill: 130.000 m3 **Soil backfill: 800.000 m3**

Confined Disposal Facility

Immersed Tunnel



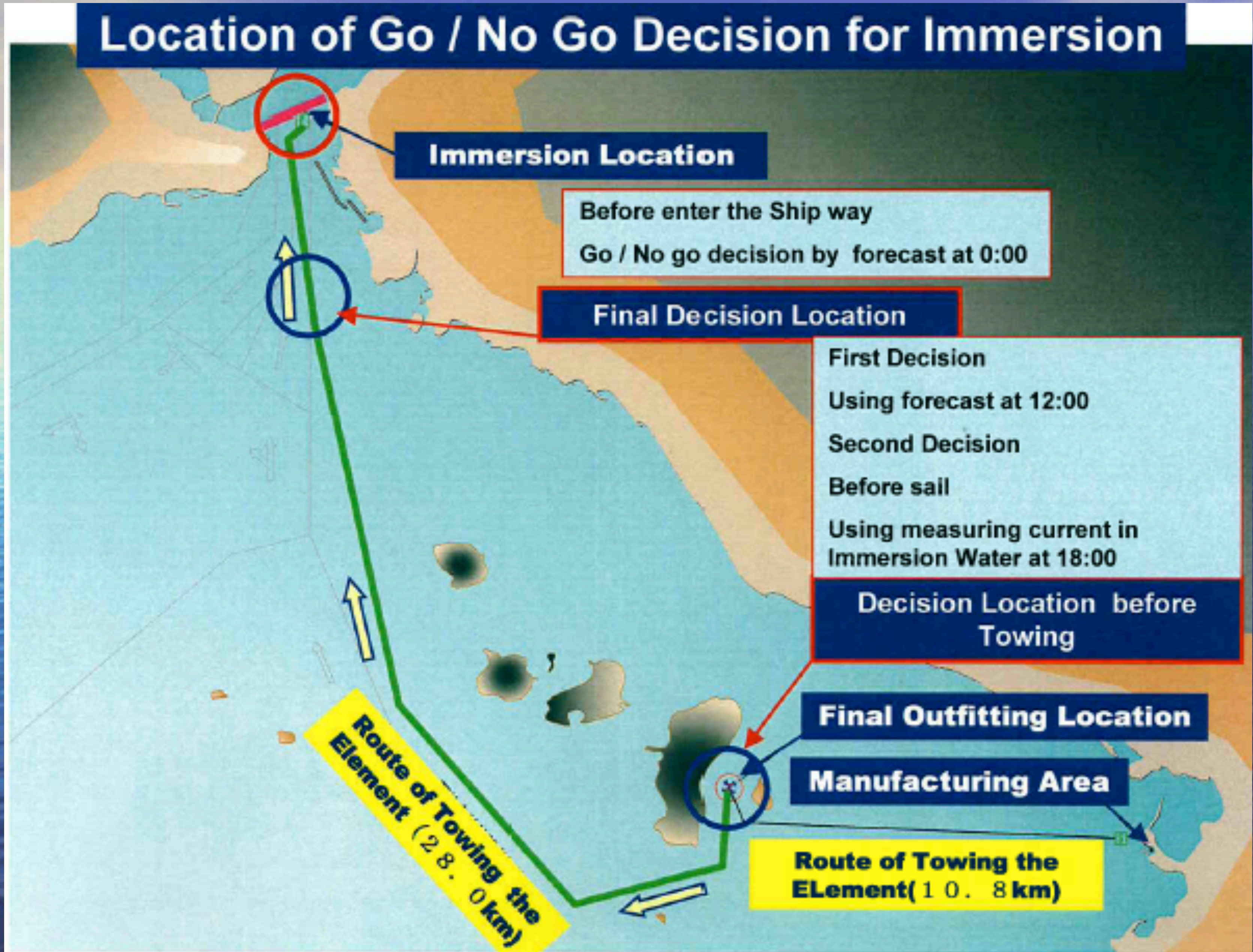
Typical Dimensions 135m x 15.5m x 8.6m, Weight = 19,000-20,000 ton

Tuzla Offshore Element Fabrication Site

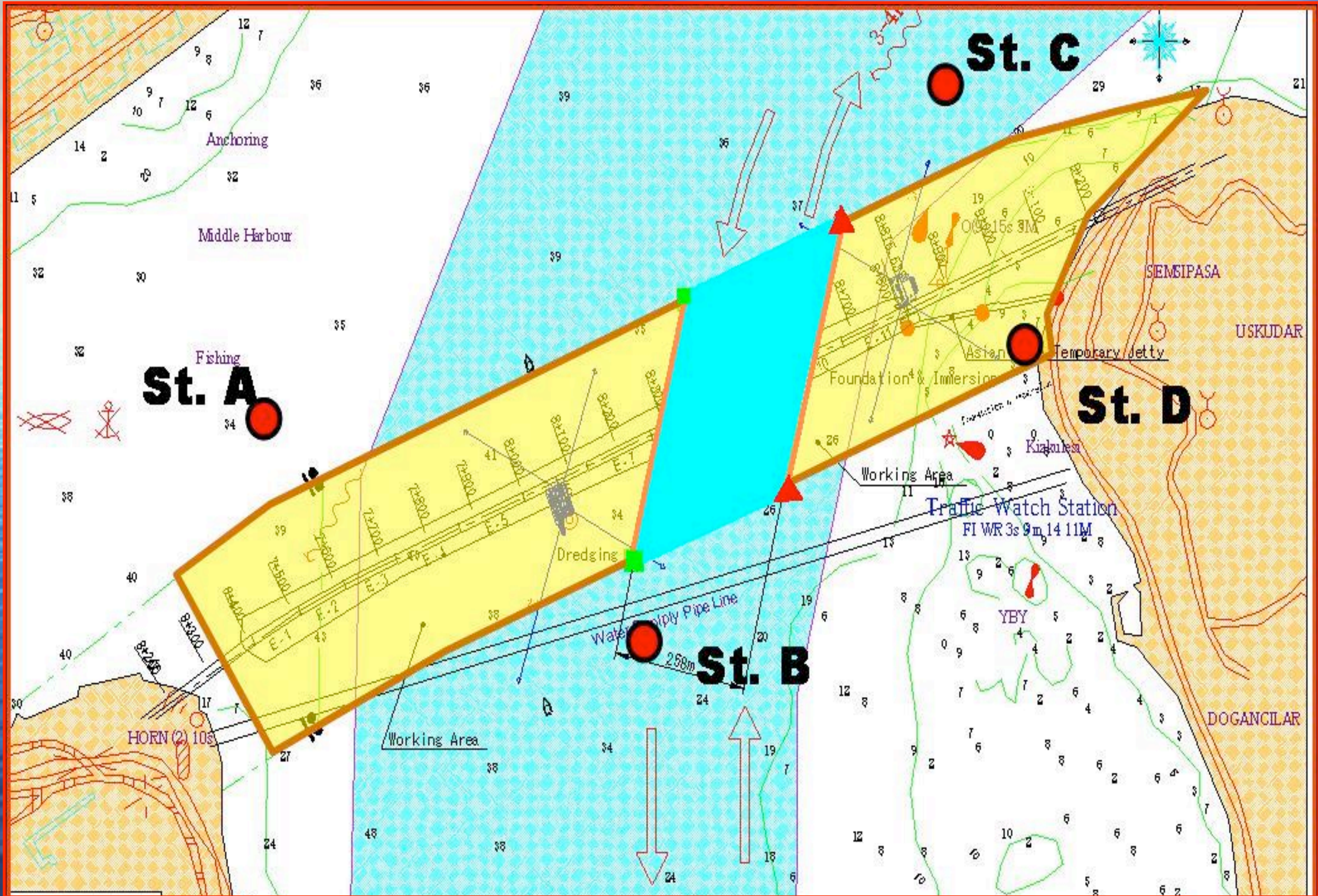
Element Fabrication in Dry Dock

Element Fabrication in Dry Dock

Elemanların yüzdürülerek Boğaza götürülmesi



Traffic Management in the Bosphorus



Access Shaft and Access Jetty

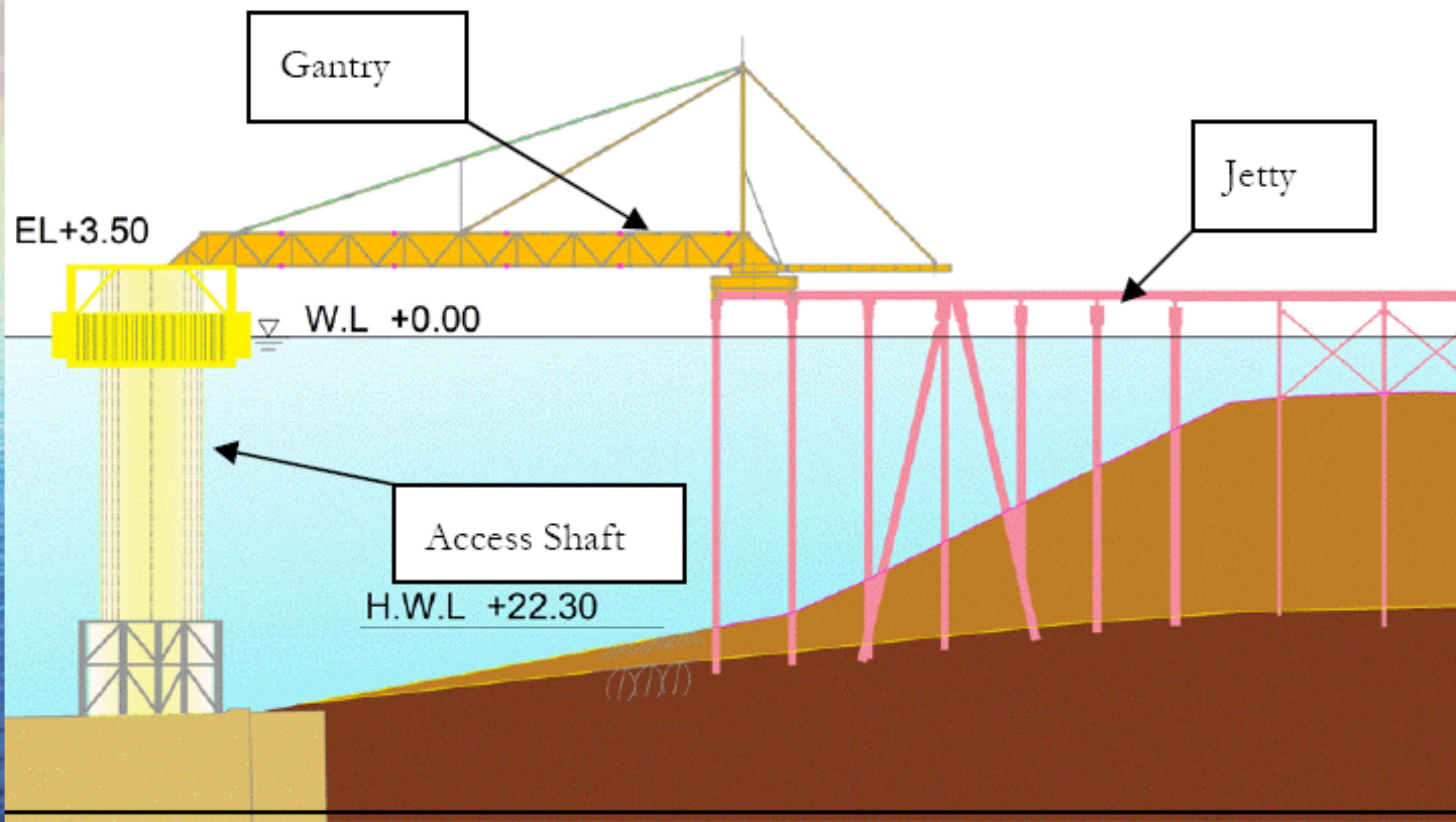
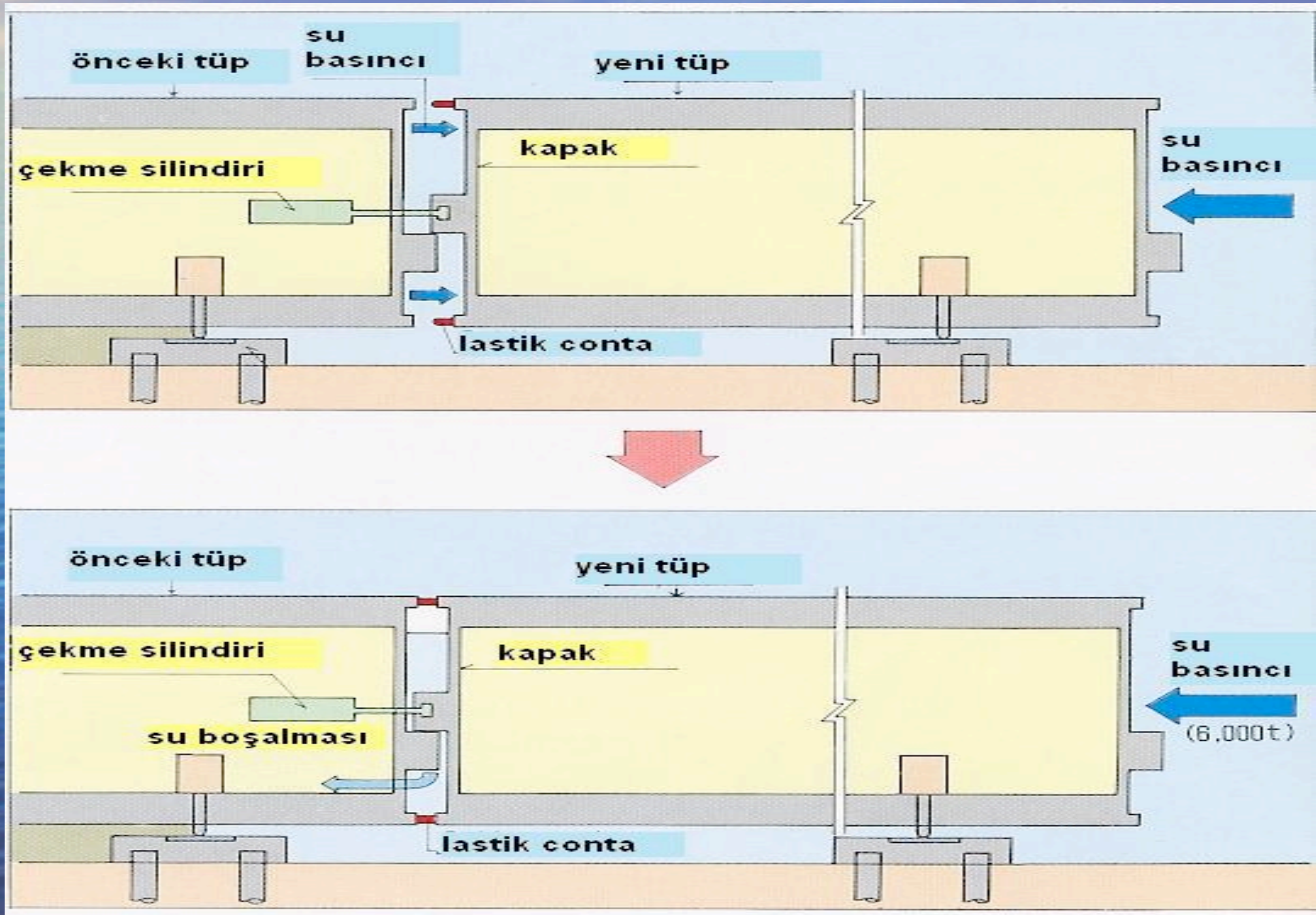


Figure 2.2 – Side Elevation of Jetty and AS Arrangement

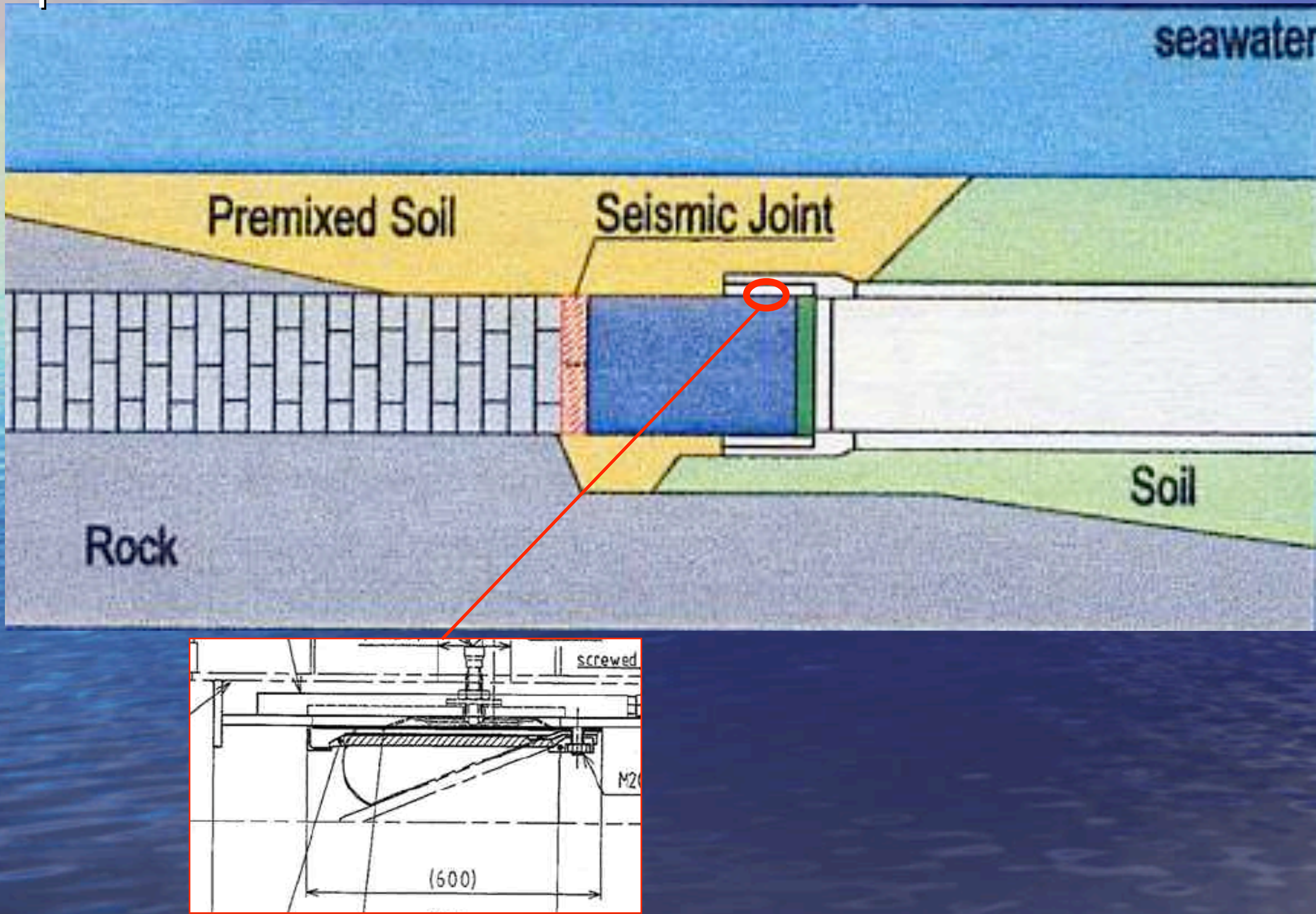
Connection of the Immersed Elements

"automatic" hydraulic connection



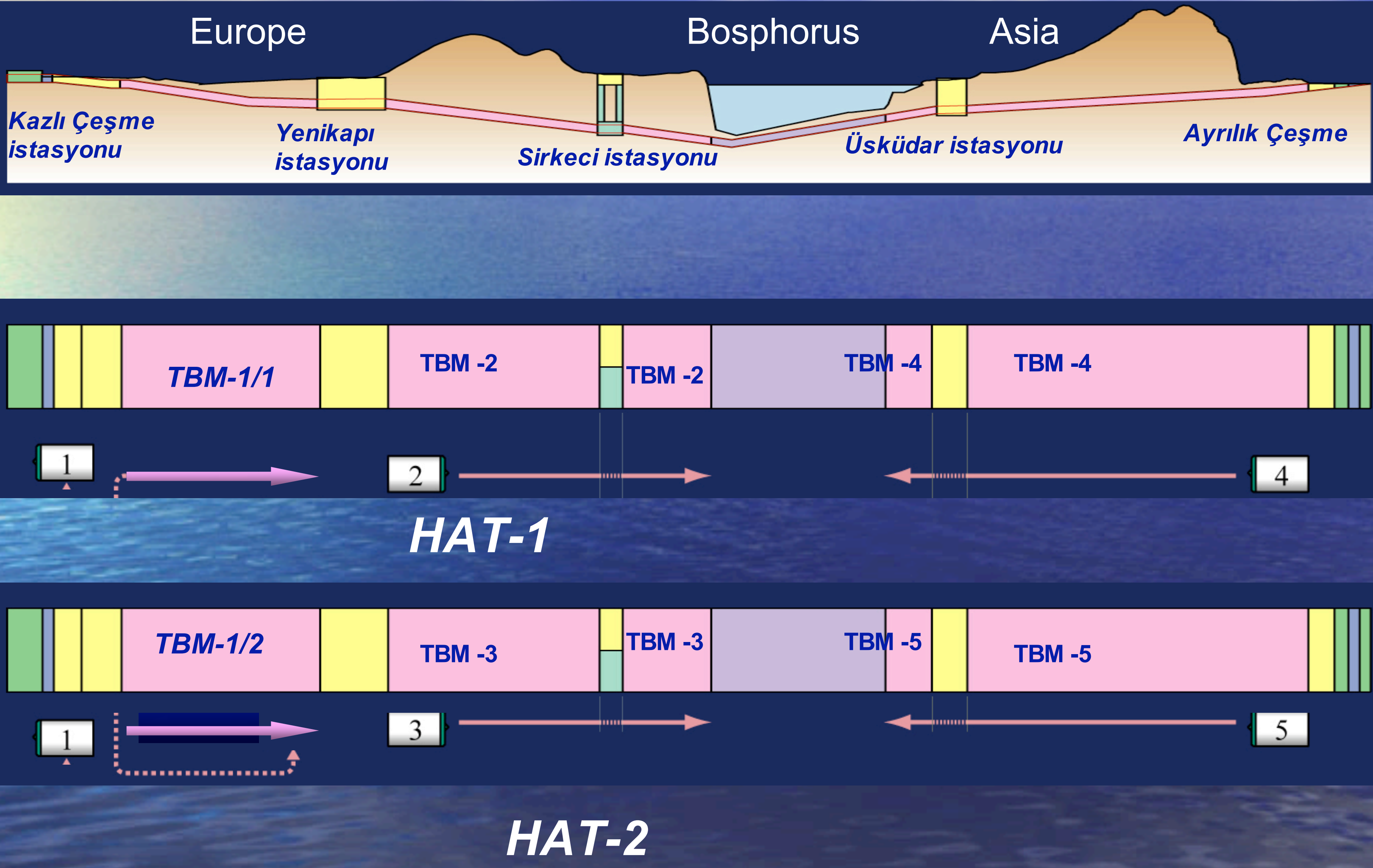
IMT&TBM Connection

- TBM Operation and drilling in to the Sleeve Pipe




TURKEY
SARIYER
BEYKOZ
İSTANBUL
YEŞILKÖY
PRINCE
ISLANDS
KARTAL
ÇINARCIK BASIN
GEBZE

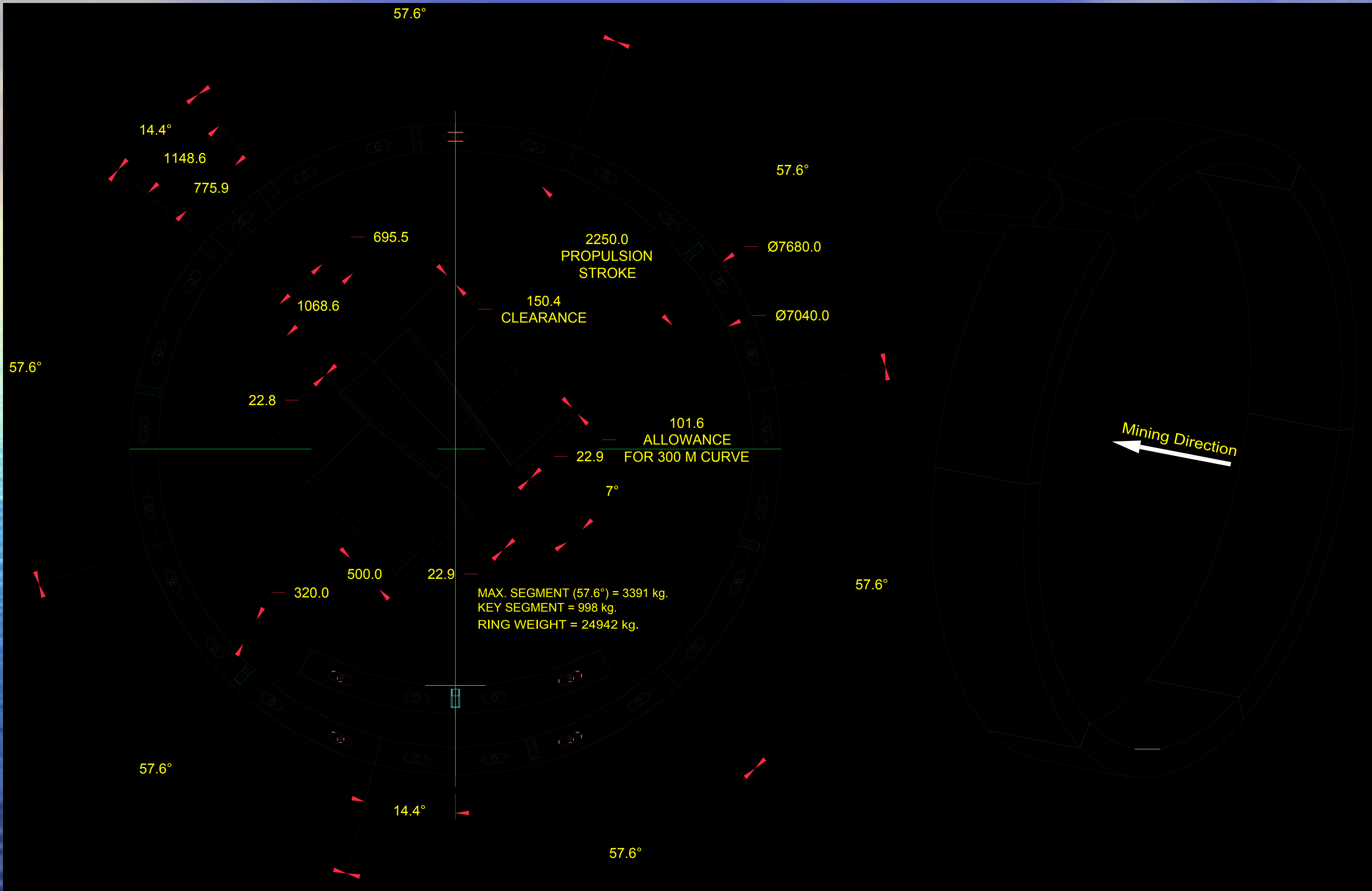
TBM TUNNELS


Europe
Bosphorus
Asia
Kazlı Çeşme istasyonu
Yenikapı istasyonu
Sirkeci istasyonu
Üsküdar istasyonu
Ayrılık Çeşme
TBM-1/1
TBM -2
TBM -2
TBM -4
TBM -4
1
2
4
HAT-1
TBM-1/2
TBM -3
TBM -3
TBM -5
TBM -5
1
3
5
HAT-2

TBM1 (EPB TYPE, YEDIKULE-YENIKAPI)

TBM4&5 (SLURRY TYPE, AYRILIKÇEŞME-ÜSKÜDAR)

TBM SEGMENTS



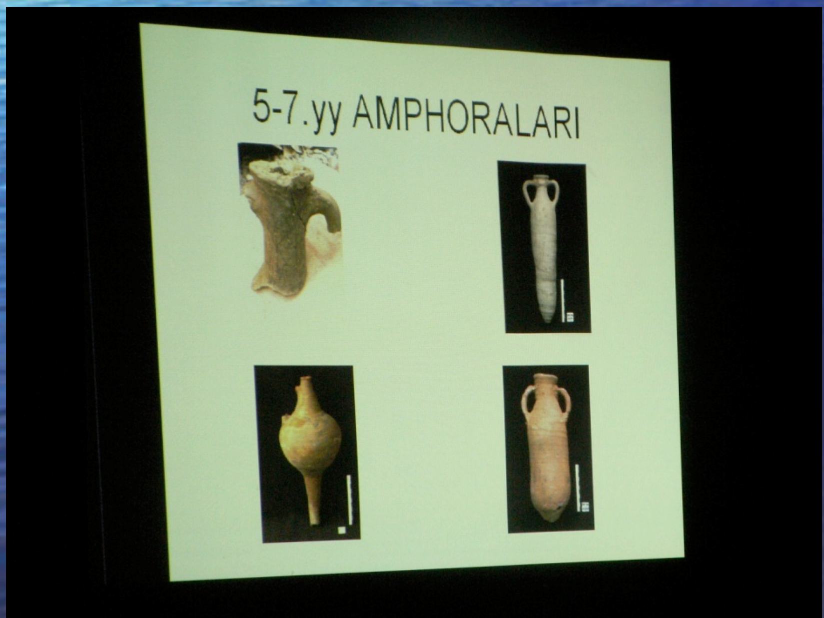
BC1 Underground Stations, Yenikapı (Cut&cover)

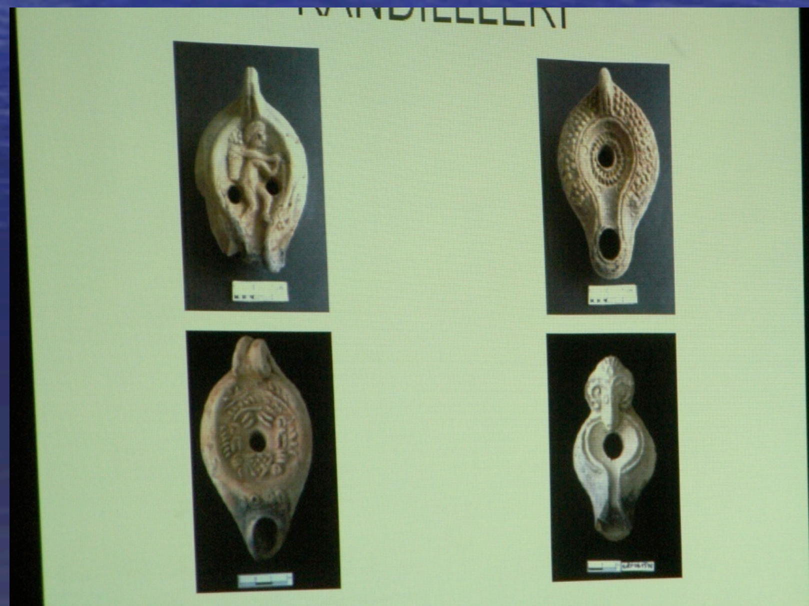
BC1 Underground Stations, Yenikapı (Cut&cover)

Potansiyel Dizayn,
Yenikapi Transfer İstasyonu

Yenikapı Station Area – Archaeological Excavation

Yenikapı Station Area – Archaeological Excavation





BC1 Underground Stations, Üsküdar (Cut&cover)

Üsküdar Station Area

www.marmaray.com

The Maiden's Tower
in the Istanbul Strait