“Immersed Tunnels”
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Overview

• Water crossings - introduction
• Design issues and how they are built
  – Some examples
• Why choose an immersed tunnel?
• Benefits of immersed tunnels
• Environmental Issues
• Project Delivery
Crossing Waterways

- Usual Options
What about an Immersed Tunnel?

• Most owners either:
  – Do not know what an immersed tunnel is,
  – Do not think of an immersed tunnel option, or
  – Dismiss an immersed tunnel option due to a perceived environmental block
What is an Immersed Tunnel?

- Precast tunnel elements, constructed in the dry
- *Float* to the destination
- Lowered into place, joined and covered up
History

• First constructed about 120 years ago.
• About 200 have been constructed all over the world.
• About 150 are for road or rail.
• First proposed 1860

Harlem River Tunnel, New York 1911
Investigation / Planning Phase

- Constraint study
- Route Selection
- Environmental impact statement
- Project risk
- Project cost
  - Whole life costs
- Economic Assessment
Investigation / Planning Phase

- Tunnels rarely are optimal at bridge locations
Constraints

- Shipping draft and depth of dredging
- Width of crossing
- Avoid rock excavation under water (cost!)
- Match ferry routes?
- Environmental issues
Ventilation

• Usually the first item to investigate
• Directly affects choice of cross-section:
  – Longitudinal and Saccardo Nozzle
  – Semi-transverse
  – Fully Transverse
Preliminary Alignments

- Internal space requirements
- Ventilation
- Preliminary estimates of structural thickness
  - Must float initially and stay submerged later
- Vertical profile and horizontal alignments
Types of Immersed Tunnel

- Concrete
- Steel
  - Single Shell
  - Double Shell (USA)
  - Sandwich (Japan)
Sandwich Tunnels

- Recent development in Japan
  - Osaka South Port
  - Naha Tunnel, Okinawa
  - Kobe Port tunnel
    - the only steel tunnel with 3-lanes per duct.
  - Bosphorus

- Both internal and external structural steel plates
- Internal steel diaphragms connect plates
- No reinforcement
- filled with non-shrink self-compacting concrete.
Concrete Immersed Tunnels

Western Harbour Crossing
Hong Kong
Double Shell Tunnels

Fort McHenry Tunnel
Fabricated in Maryland
Single Shell Tunnels

Cross Harbour Tunnel, Hong Kong

Söderström, Sweden

BART, San Francisco
Bosphorus - Sandwich Portion
Why Immersed Tunnels?

• Not for every situation
• Water to cross?
  • Feasible alternative to bored tunnels
  • Comparable price
  • Special advantages
Advantages

• Any cross-section, esp.
  • Wide highways

I-95 Fort McHenry, Baltimore, MD
Combined Road-Rail Tunnels

Øresund, Denmark (Drogden Channel)
Concrete 2+2 Road & 1+1 Rail
Why Immersed Tunnels?

- Very soft ground *no problem*
- Earthquakes *can be handled*
- High quality *from precasting*
- *Flexible* construction programme
- Less risky *than bored tunnel*
- Have been built in *busy waterways*
- Ideal for *tall ships* where soils are poor
- They don’t spoil the view!
Myths about Tunnels:
Tunnel elements are full of water

- Bulkheads (dam plates) across the ends keep the insides dry.
- Only about 2 m between bulkheads need to be emptied.
- Some internal water ballast in tanks may be used during installation.
Design Requirements

• No codes for immersed tunnels
• Design load factors different
• ITA WG-11 State-of-the-Art Reports
• Conferences
  – ITA WG-11 and ITA-CET
  – Papers
• Other jobs
• AASHTO
  – Technical Manual for Design and Construction of Road Tunnels – Civil Elements, Sept 2010
Design Basis

- The necessary weight of an immersed tunnel is determined only by the volume of its internal spaces, not by its construction method.
Crack Control – Cooling of Concrete in Outer Walls
Waterproofing

• Engineers divided about the need  
  – I have always recommended it  
• External  
  – Waterproofing to adhere or be limited in panels  
• Joints  
  – Swelling rubber waterstop best  
  – Avoid reinjectable grout tubes
Elements – Monolithic or Segmental?

- **Monolithic**
  - Better for varying ground conditions
  - Better for rail tunnels (less differential settlement)
  - Avoidance of cracking more difficult

- **Segmental**
  - Avoidance of cracking much easier
  - More joints to leak
  - Shear transfer required at every joint
  - Minimum longitudinal reinforcement
  - Needs temporary longitudinal prestress
Ted Williams Tunnel
Fabricated in Maryland
Dredge a Trench

- Dredging methods
  - Closed clamshell
- Dredged material disposal
- Future water depths
Foundation Methods

- Screeded foundation placed before element immersion and joining
- Pumped sand foundation placed after element supported in place on temporary supports
- Special grout
Outfitting Site

- Finish elements
- Ready them for immersion
- Attach elements to winches or cranes
- Pontoons or barges needed
Survey Towers

Western Harbour Crossing
Hong Kong
Compression of Rubber Gasket
Completing the Installation

Backfilling

Temporary ballast

Rock protection layer

Permanent ballast (asphalt)
Finishing

- Foundation
- Backfill trench
- Protect top of tunnel
- Finish insides
Land-side Interfaces

- Ventilation buildings
- Earthquake joints
- Cut-and-cover tunnel
- Open approaches
- Sequence IMT-C&C schedule driven
Immersed Tunnel Challenges

• Use Advanced Construction Techniques
• Use Latest Ventilation Techniques
• Select ideal Immersed Tunnel Alignments
• Determine Construction and Staging Locations
• Deal with Difficult Ground Conditions
• Dredging and Disposal
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Something to celebrate:
Øresund Tunnel pre-opening day