The tunnelling industry in Holland

Revealing case study examples and lessons learnt from recent projects and the future outlook for underground construction in the region

Jan Jonker
Predrag Jovanovic
KIVI NIRIA TTOW
Movares
Utrecht, the Netherlands
– Developments in technology and the design philosophy behind tunnelling in Holland

– Highlighting the use of innovative technology in recent projects and the implications this has for the future of the industry

– Evaluating the latest research and in this field and the extent to which lessons can be learnt from the Netherlands
16 million people
20% water
300x200 Km
Some facts (1991)

• Since 1991 strong economical grow of Dutch economy with low unemployment
• One of the world’s most densely populated nations
• Rotterdam is the biggest port in the world
• Connection with the fright and HSL within EU
• More mobility (traffic, transportation)
• More investments in infrastructure
• Less space above ground
• Uncertainties underground
• Environmental protection and safety requirements the first priority
Tunnelling in the Netherlands

- In last couple of decades there are 3 important construction technologies developed and improved:
  - **Immersed tunnels**
    - 1942 – the first big immersed tunnel - Maas tunnel in Rotterdam,
    - Up to 2011 – 30 tunnels in the Netherlands and more than 10 abroad
  - **Cut & Cover tunnels inclusive Land tunnels**
    - 1957 – the first implemented at Velsertunnel under Noordzeekanaal Schiphol tunnel, Railway tunnel Best, HSL Rotterdam, Zevenaar tunnel
    - 2010-2011 - Land tunnels: A2-Amsterdam Utrecht, A4-Delft Schiedam
  - **Shield driven tunnels (TBM)**
    - 1995 – 1st pilot – the 2nd Heinenoordtunnel
    - 1997 – 2nd pilot – Botlek railway tunnel
    - Up to 2011 – 8 TBM tunnels constructed
1991 – Infrastructure Going Underground - Actions

• Ministry of Transport established steering committee for infrastructure (SOVI) to find the answers about all relevant questions concerning underground policy

• Center for Civil Engineering Research and Codes (CUR) was involved to initiate the program and to make a link between private and public sectors

• CUR/COB - Center of Underground Construction is created to initiate and coordinate R&D program on shield driven tunnel technology (the 2nd Heinenoord tunnel and Botlek railway tunnel) between 1994 and 1999

• TU Delft established the new department named Underground Construction

• COB initiate a clients platform for mutual research programs (GPB)

• Master plan for GPB created for the future research

• Improvement of the existing immersed and cut & cover techniques remains
Participants

– Ministries (MT&WM, MEA,..)

– Mayor Projects (HSL South, Betuweroute, NZL,....)

– Dutch Railways

– Consultants (Movares, Arcadis, DHV, W&B, TEC,....)

– Delft Cluster (TNO, GeoDelft, WL, TU Delft,.......)

– Institutes, universities, contractors, etc
Some of the main goals

• To gain knowledge and experience with TBM technology in very soft soils
• To develop reliable methodology for the tunnels
• Low life cycle costs
• Getting optimum solution for the Underground Space
• To develop optimum safety and security solution
• Full environmental protection
• Optimization of legal issues
• Low risk profile
• Optimization of contract forms
• Stimulation of cooperation and innovations
Dedicated research program to gain knowledge and experience concerning bored tunnels:

- TBM Technology
- Geotechnical engineering
- Lining engineering
- Construction methodology
- Dynamics, noise and vibrations
- Safety issues
- Environmental issues
- Logistics
- Risk Management
- Project and Contracting management
Achievements in last 20 years

• Successful policy based on cooperation between all participants obtaining pole position in EU
• Tunnels with higher quality, reliability and safety
• Lower initial, construction and maintenance costs
• Faster, better and cheaper - comparable with bridges
• Less claims, disruptions and settlements
• Making possible future developments of underground space in the Netherlands
• Export of extensive knowledge concerning submerged tunnels (Fehmarn Belt, Denmark – TCH, Busan, Korea – Strukton)
Overview large tunnels in the Netherlands

- **HSL - South Green Heart**
  - Hubertus tunnel
  - Road tunnel ø 10.0 m
  - 1 x 6,570 m

- **The Hague**
  - Hubertus tunnel
  - Road tunnel ø 10.0 m

- **Rotterdam**
  - Metro tunnel ø 6.65 m
  - 2 x 2,000 m

- **Westerschelde**
  - Highway tunnel ø 11 m
  - 2 x 6,600 m

- **Sluiskil tunnel**
  - Highway tunnel ø 11 m
  - 2 x 1,100 m

- **Amsterdam**
  - The 2nd Coentunnel
  - Road submerged tunnel
  - 1,300 m, 26 m

- **Amsterdam NZL**
  - Metro tunnel ø 6,65 m
  - 2 x 3,800 m

- **Amsterdam NZL**
  - Submerged tunnel under the Central Station

- **Betuweroute**
  - Railway tunnel ø 10,0 m
  - 3 shield tunnels
  - Total 2 x 7,660 m

- **The 2nd Heijnenoord**
  - Road tunnel ø 8,3 m
  - 2 x 950 m
The Second Heinenoord Tunnel

The first pilot project 1995
Extensive monitoring program
First bored front instability
Botlek Railway Tunnel
First time EPB shield

The second pilot project 1997
Extensive monitoring program
Two component grout

Ground improvement
The particular challenge that faces the construction of the Westerschelde Tunnel is the soft clay that has to be bored through.
Cross passages
26 cross passages running every 250m were built using ground freezing methods for the first time.

Leakages – tail brushes
Sophiaspoortunnel - 2000
Continuum bored process
Blow-in

Damages, cutter head
Reparations from the surface

Lining
Damages, cracks
Tunnel Pannerdensch Kanaal – 2001

Drilling through existing embankment
Green Heart Tunnel
High Speed Line

Worlds largest TBM in 2003, D = 14.9 m
No damages
Flat joints
jacks configuration
Largest diameter
Masterplan GPB II 2005

Extension:

• Laboratory test of drilling - TU Stevinlab
• ULS tests of the 3 rings TC 151
• Randstadrail tunnel Rotterdam
• Hubertustunnel Den Haag
• Metro Amsterdam
Randstadrail Rotterdam
Hubertus tunnel Den Haag - 2008

Drilling under the city
Summary

- Knowledge gained from practical experience
- Lot of prediction reports, measurements and evaluation reports
- The state of the art concerning bored tunnels is on a high level
- Unpredicted things could always happen (cracks, damages, abrasions, blow out, blow in, deformation of the shield, leakages of the tail brush, etc)
- Lessons learned at the pilot projects implemented on the other projects (Green Heart tunnel, Hubertus tunnel – no unpredicted things from above happened)
- Export of extensive knowledge concerning immersed tunnels (Fehmarnbelt, Denmark – TEC, Busan, Korea – Strukton)
Running projects
NZL – metro Amsterdam
Station on new foundations
Vertical drilling
Tubex piles
No settlements
Submerged tunnel under station
NZL – metro Amsterdam
Compensation - grouting to avoid settlement

Proef bij Sophiaspoortunnel

- Shaft
- Injection body
- Tunnel
Spoorzone Delft – Cut & Cover tunnel
2de Coen tunnel Amsterdam – Submerged tunnel
A2 – Maastricht – Cut & Cover
A2 – Amsterdam Utrecht – Land tunnel
A4 – Delft Schiedam Land Tunnel
Sluiskil Tunnel – TBM tunnel
Busan-Geoje, Korea
Strukton

60 m deep
Fehmarn Belt, Denmark – consultant TEC, 20 Km long
Future projects
Rotterdamsebaan – The Hague 2013
Road tunnel - TBM
Amsterdam Zuidas 2013
Ijmeer verbinding – metro Amsterdam Almere 2014
4,5 Km long – immersed tunnel
Oranjetunnel and Blankenburg tunnel – Rotterdam 2015
Conclusions

- TBM tunnels in the Netherlands soft soils are, since 1995, the reality.
- It is possible to control settlements in extremely difficult soft soil conditions in the cities.
- Life Cycle Costs can be significantly reduced if the Risk Management Control is applied from the beginning of the project.
- Approved design philosophy verified in practice and laboratories is the basis (prediction, observation, evaluation, action, mitigation).
- Appropriate mitigation is essential for the total costs (design, procedure, verification, validation).
- Mutual effort (public and private) leaded the Netherlands to the pole position worldwide concerning the knowledge about the shield driven tunnelling in soft soils.
- The total costs of the TBM tunnels are close to the cost of the equivalent bridges.
Conclusions

• Cut & Cover tunnels are common practice in the Netherlands
• Land tunnels are gaining more space because of environmental and landscape requirements
• The Netherlands keep the pole position worldwide concerning design (TEC) and construction (Strukton) of the immersed tunnel
• Immersed tunnels are getting longer (20 Km FB) and deeper (Busan – 60m)
• Costs of immersed tunnels are comparable with the bridges (Ijmeerverbinding)
• More interest from abroad on immersed tunnels (Asia, Middle East, Brassily, etc)
• Optimization of the immersed tunnels is still ongoing process