Tunnel Engineering Consultants

Tunnels & Tunnelling

Experience Record

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TEC Tunnel Engineering Consultants

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INTRODUCTION

Tunnel Engineering Consultants (TEC) is a Joint Venture of Royal HaskoningDHV (RHDHV) and Witteveen+Bos (W+B). TEC combines knowledge, expertise and experience of the mother companies (8000 professionals) within the field of large underground projects.

TEC guarantees continuity and specialized knowledge of tunnel design and construction to solve complicated underground mobility challenges through an integral, innovative and sustainable project approach.

In addition, TEC is able to draw on the considerable expertise of two Dutch engineering consultancy firms and covering the entire range of civil, structural and architectural engineering required for small and large building projects, environmental impact assessment, legal aspects and project management.

This TEC experience record intends to give an impression of the capabilities of Tunnel Engineering Consultants in the field of tunnel related design and tunnel construction related consultancy. It will provide an overview of services that TEC can offer within the preparation and realization of tunnel project.

This document provides a selection of appealing projects in which TEC was and is involved including the position TEC had in the project.

TEC PROFILE

Tunnel Engineering Consultants v.o.f. (TEC) is specialised in consultancy works for underground infrastructure and tunnel projects. TEC is established in 1988 as a Joint Venture between two major engineering consultancy firms:

- Royal HaskoningDHV
- Witteveen+Bos Consulting Engineers b.v.

Profile

TEC's key expertise is tunnels; in-situ land tunnels, bored as well as Cut&Cover and immersed tube tunnels. The Scope of work comprises tunnel design with construction supervision including the mechanical and electrical tunnel installations. Together with the Dutch Ministry of Transport and Public Works – Tunnel engineering Department (Rijkswaterstaat), TEC developed advanced knowledge in tunnel engineering.

The participating firms employ more than 8000 engineers and specialists and have a total annual turnover of about 748 million EURO (2016). They have subsidiaries and branch offices in countries worldwide.

Royal HaskoningDHV

Royal HaskoningDHV
Enhancing Society Together

www.royalhaskoningdhv.com

Royal HaskoningDHV is a leading independent, international project management and engineering consultancy service provider. Specialising in planning and transport, infrastructure, water, maritime, aviation, industry, energy, mining and buildings, each year we contribute to the delivery of some 30,000 projects around the world on behalf of our public and private sector clients.

Our 6,500 staff adds value to our client's projects by providing a local professional service in more than 35 countries, via our fully integrated international office network. As leaders in sustainability and innovation, we are deeply committed to continuous improvement, business integrity and sustainable development, and work with our clients, stakeholders and communities to enhance society together.

Prior to the merger on 1 July 2012, Royal Haskoning and DHV have successfully delivered millions of world class projects during the past two centuries. With roots established in The Netherlands, the UK and South Africa, our combined experience and longevity spans more than 225 years. Now, as one company, we have the power to make a bigger difference in the world as we rise to the challenges of our 21st century planet, towards a better, brighter future.

Today Royal HaskoningDHV ranks in the top 10 of global, independently owned, non-listed companies and top 40 overall. This makes us the first-choice consultancy provider for involvement in major world themes, such as 'pit-to-port', food and water scarcity, the development of mega-cities, and sustainable infrastructure and energy resources & supply, such as wave and hydro power. We are also well positioned to contribute to the latest business models, such as Public-Private Partnership.

Witteveen+Bos Consulting Engineers b.v.

www.witteveenbos.com

Witteveen+Bos is a private limited company whose shares are owned entirely by its employees, who are either participants, partners or senior partners. This unique ownership structure ensures above-average commitment, good financial performance and a high profile. It is a structure that appeals to our clients because it gives them confidence in our commitment. Our net result is paid out entirely as a dividend to our shareholders, so they share in large measure in the company's result.

The Witteveen+Bos organisation is built around the cells concept that we have shaped in the form of PMCs (product market combinations). Organisationally, the PMCs are clustered into five sectors. The five sectors are: Ports and hydraulic engineering, Spatial development and the environment, Urban development and traffic, Water, and Infrastructure and Construction,

Next to the offices in The Netherlands, Witteveen+Bos also has offices in Belgium, Kazakhstan, Indonesia, Russia and Latvia.

Witteveen+Bos is committed to being a first-rate consultancy and engineering firm. Performing at the very highest level is a precondition for achieving this goal. We think striving for the top is a healthy ambition. A national and international orientation towards products, markets and the labour market is essential to operating being the best in our field of work.

Internationally, Witteveen+Bos has achieved a good position in the following areas:

- preparation, transport and distribution of drinking water
- effluent treatment
- water management
- environmental technology and policy
- ports, dredging, coastal water engineering, river water engineering
- tunnels

SERVICES

TEC provides a full range of consultancy services from feasibility studies, design, tender documents, tender evaluation, design reviews, value engineering, cost analysis, detailed design, and construction supervision to project management for underground engineering, related electrical and mechanical works and traffic engineering. In addition, we are able to draw on the considerable expertise of two Dutch engineering consultancy firms covering the entire range of civil, structural and architectural engineering required for small and large building projects, environmental impact assessment, legal aspects and project management.
Moreover, TEC has at their disposal specific expertise of the Dutch Ministry of Transport and Public works – Tunnel Engineering Department (Rijkswaterstaat), a governmental organisation involved as designer and owner / operator in about 26 road and railway tunnels and their installations in the Netherlands.

Expertise

- Civil
  - immersed tunnels
  - shield tunnels in soft soil
  - cut & cover tunnels
  - pneumatic caissons
- Electro mechanical installations
  - ventilation
  - pumps
  - lighting
  - power supply
  - traffic control
  - operation
- Safety aspects
  - Safety analysis
  - Operational procedures
  - QRA and Scenario Analysis
- Risk assessment & Value Engineering

IMMERSED TUNNELS

General

TEC is recognized as an international specialist in soft ground tunnelling and one of the very few international leading consultants in the field of immersed tunnelling. This allows TEC to make in depth comparisons taking into account all available tunnel options and to select, depending on the various project conditions, the right solution for our client. TEC is and has been involved in numerous immersed tunnel projects including major sea crossings. In the various projects TEC held positions from Client Consultant to Detailed Design Engineer for a Contractor, which is considered essential to cover all individual project phases in order to remain the top-class consultant and engineer for every Customer (see quote).

Through involvement in various challenging tunnel projects, TEC is perfectly capable of selecting the most suitable tunnel option, being of added value to every infrastructural underground project.

TEC’s ongoing involvement in major infrastructural tunnel projects guarantees TEC’s key position in international tunnelling. To date TEC was involved in over 50 immersed tunnel projects. On the following pages a selection of the TEC Immersed Tunnel projects is briefly described.

TEC has been involved in the following immersed tunnel projects, either through the TEC entity or through one of its partners:

- Noord (North) tunnel, the Netherlands
- Western Harbour Crossing, Hong Kong
- Tunnel under the Rio Guadalquivir, Seville, Spain
- Medway tunnel, Chatham-Rochester, United Kingdom
- Wijker tunnel, Velsen, The Netherlands
- Piet Hein tunnel, Amsterdam, The Netherlands
- Maliakos Gulf crossing, Greece
- Øresund Link, Denmark-Sweden
- Chang Hong immersed tunnel, Ningbo, China
- Aktio – Preveza Crossing, Greece
- Daugava river tunnel, Riga, Latvia
- Warnow Crossing, Rostock, Germany
- HSL tunnel Oude Maas, The Netherlands
- HSL tunnel Dordtsche Kil, The Netherlands
- Thomassen (Caland)-tunnel, the Netherlands
- Thessaloniki Immersed Tunnel, Greece
- Shannon river tunnel, Limerick, Ireland
- River Tyne crossing, Newcastle, United Kingdom
- Busan – Geoje Link, South Korea
- Coatzacoalcos tunnel, Mexico
- Immersed Tunnels in North/South Metro line, The Netherlands
- Project Immersed tunnel under the IJ-river
- Crossing under Amsterdam Central Railway Station
- 2nd Coentunnel, Amsterdam, The Netherlands
- Oosterweel tunnel, Antwerp, Belgium
- Hong Kong – Zhuhai – Macau Link, China
- Fehmarnbelt immersed tunnel, Denmark-Germany
- Shenzhong crossing China
- Söderström, Sweden
- Santos-Guarujà Crossing, São Paulo, Brazil
- Sharq Crossing Doha, Qatar
- Marieholmstunnel, Gothenburg, Sweden
- ShenZhong Link International Design Competition, China
- Shatin to Center Link, contract 1121, HongKong, China
- Rupel tunnel, Belgium
- Chesapeake Bay Bridge tunnel, USA
- DBFM Blankenburg Link A24, the Netherlands
- Shanghai Outer Ring Tunnel, China
- Golden Horn Unkapanı Tube Tunnel
- Limfjord tunnel, Aalborg Denmark

Noord (North) tunnel, the Netherlands

Project

To solve the daily traffic congestions at the crossing of the river Noord on the A15 motorway, the 2x2 lane arched bridge was replaced by a new 2x3 lane tunnel. The new, approx. 1.300 m long tunnel on the A15 motorway comprises:

- Two approaches (open ramp structure, using geotextile to create a polder and conventional cut and cover tunnels).
- An immersed tunnel section, consisting of 4 concrete tunnel elements (3 x 130m and 1 x 100 m).

The tunnel cross section contains two traffic tubes with three lanes each and a central duct for emergency and to house utilities.

The new tunnel was classified as a category I tunnel and therefore accommodated to allow the passage of hazardous goods.

The tunnel elements were built in an existing casting basin that is owned by the Public Works (and that was used for other tunnels). The casting basin was shared with another project. Along with the elements for the Noord Tunnel also the tunnel elements for the Willem Rail tunnel were built. To avoid large scale dredging on the transport route the roof of the tunnel elements was only casted partially. The remaining part of the roof was being cast upon arrival at the project location prior to the fitting out of the tunnel elements for immersion.

The mechanical and electrical installations for the Noord tunnel comprise:

- Energy supply
- Tunnel lighting
- Drainage and tunnel ventilation
- Traffic installations
- Fire fighting provisions
- Communication systems
- Maintenance building installations
- Plant control and control systems

Figure: Tunnel under the river Noord

Figure: Tunnel interior

TEC's scope of work

Overall:

- Representation of the Employer during the construction phase, carrying out site supervision and contract-administration for the execution of all tunnel civil and installation works.

Civil and Structural works:

- Update and optimization of final design including the draft tender documentation and drawings.
- Detailed design of all civil works including construction and reinforcement drawings.
- Review of contractors' detailed engineering for all temporary works, including the transportation and immersion equipment, the artificial cooling design for the avoidance of early age thermal cracking.

Mechanical and Electrical:

- Preparation of the conceptual design / project definition.
- Development of the tender documents that also included traffic management and remote control of the Noord tunnel and other tunnel and bridges located in the region.
- Preparation of Terms of References, to control and check the contractors detailed design
- Review of contractors' detailed engineering for all tunnel systems (M&E including traffic management systems).

Western Harbour Crossing, Hong Kong

Project

The 35 kilometre road between the new Chek Lap Kok airport and Hong Kong Island includes several bridges and a tunnel. The tunnel, the Western Harbour Crossing is located in the western part of Victoria Harbour between the Kowloon extension and Hong Kong Island. The Western Harbour Crossing will be a privately financed BOT project. The Cross Harbour Tunnel Co. Ltd. was one of the competing franchises for this project. Together with Mott Connell Hong Kong, TEC was invited to prepare a tender design for this tunnel project.

The tunnel alignment has a length of 2750 metre, and accommodates 3 traffic lanes in each of the two traffic tubes. The tunnel also accommodates a central corridor. At Kowloon the tunnel is built as an in-situ cut and cover tunnel in the new land reclamation. The immersed section measures 1290 metre and consists of eleven elements. At Hong Kong Island the approach is built as a top down cut and cover tunnel structure, using diaphragm wall reaching 50 m deep onto the bed rock.

Figure: tunnel in operation (source: internet)

TEC's scope of work

As member of a design consortium TEC prepared the tender design for the immersed tunnel section, the Kowloon entrance, vertical alignment and cross section. The Client was the Cross Harbour Tunnel Co. Ltd., one of the competing consortia for this BOT project.

Tunnel under the Rio Guadalquivir, Seville, Spain

Project

The tunnel crosses the Rio Guadalquivir as part of a dedicated public two by two lanes highway, class I standard, linking the banks of the river Rio Guadalquivir. The total length of the immersed section is 700m. In the design, the elements would be constructed in a temporary construction dock near the site and would have a length of approximately 125 m each.

TEC's scope of work

TEC provided the tender design for the immersed tunnel, the cut and cover tunnels for the approaches (permanent structures and temporary works) and prepared a design for the casting basin.

Medway tunnel, Chatham-Rochester, United Kingdom

Project

The Medway Tunnel is a dual carriageway motorway tunnel. In the enclosed part the two traffic tubes are only separated by a central wall. The tunnel width is 24 m. The actual structures are 1800 m long including a 600 m enclosed section and the tunnel approaches.

The immersed part of the tunnel consists of 3 elements of which two of 126 m and one of 120 m. All elements are built in the eastern approach. The project is tendered according to the “design and construct” method of the ICE.

Figure: Medway tunnel under construction (top left, right) and completed (bottom left)

TEC’s scope of work

When the project was award, TEC delivered support to Mott MacDonald for the design of the tunnel, casting basin, the trench, immersion facilities and supervision of the works to the contractor Tarmac Construction Ltd. / HBM Civil Engineering Ltd. Furthermore TEC carried out an independent design check category II on the immersed tunnel part.

Wijker tunnel, Velsen, The Netherlands

Project
This motorway tunnel has two tubes each comprising three lanes and a central duct. The tunnel is part of the new A9 / A22 motorway situated 1200 m east of the existing Velser tunnel, where it crosses the North Sea Canal.

The tunnel and the approaches, wide 30 m, long 1100 m have been designed for the transportation of hazardous goods, category I standards. The immersed part of the tunnel consists of 6 elements, each 96 m long. The elements have been constructed in a casting basin at Barendrecht and then transported via the North Sea to the North Sea Canal. Both approaches consist of three 20 m long tunnel sections and five open ramp sections. These reinforced concrete structures have been constructed by means of the cut and cover method. The upper part of the approaches, some 500 m, are so called “green” approaches and are built using the polder principle with soil-ballasted watertight PVC membranes.

The mechanical and electrical installations for the Wijker-tunnel comprising:

- Energy supply
- Tunnel lighting
- Drainage and pumps
- Tunnel ventilation
- Traffic installations
- Fire fighting provisions
- Communication systems
- Maintenance building installations
- Plant control system

Figure: Wijkertunnel location

TEC's scope of work

Overall:

- Representing the employer during construction and carry out site supervision and contract-administration for the tunnel works construction and installations.
- Probabilistic analyses concerning the sea transportation of the tunnel elements on the North Sea.
- Review of contractors' detailed design for the temporary works.

Civil and Structural works:

- Design responsibility, update and optimise the draft tender design, tender documentation and tender drawings.
- Detailed design for all permanent works.

Mechanical and Electrical:

- Preparation of conceptual design.
- Preparation of Terms of References and tender documentation,
- Review contractors detailed design
- Site supervision.

Figure: transport tunnel elements

Piet Hein tunnel, Amsterdam, The Netherlands

Project

The Piet Hein tunnel is part of the road link between Amsterdam Central Station and the A10-ring road and the new suburb IJburg on reclaimed land. The tunnel has a total length of 1.9 km and provides a road and rail connection between the eastern waterfront of Amsterdam and the Amsterdam Ring road.

The tunnel cross section has four tubes, two of which are reserved for road traffic, each with a width of 8.5 m. One tube is reserved for the tram line with a width of 9.1 m, and one tube is reserved for the service and escape gallery with a width of 1.5 m. The service gallery is located between the two road traffic tubes and is also used as an escape route.

The immersed part of the tunnel is approx. 1.265 m long and made up of 8 reinforced concrete tunnel elements, each with a length of approximately 160 m.

Figure: Tunnel elements in construction dock (Verrebroek dock Antwerp)

The immersed tunnel is connected to transition structures (piled abutment structures) on both banks, with a length of approx. 60m each. The transition structures also include the service buildings for the operation of two tunnels including the Piet Hein tunnel.

The western approach is about 215 m long of which approximately 40 m is a conventional cut&cover tunnel having the sheet piles (used for construction) incorporated in the final structure. About 175 m is a structure based on a polder principle with permanent sheet piles extending down to semi impermeable soil layers and a permanent horizontal drainage system.

The eastern approach is approx. 295 m long. A deep open approach structure of around 170 m is connected to the transition structure and consists of a concrete floor slab.

Figure: Offshore transport Tunnel elements on the North Sea

The immersed sections were built off-site at a dock near the Belgium city of Antwerp. Each section was towed offshore across the North Sea from Antwerp to Amsterdam and immersed into place.

TEC's scope of work

For the Belgium Construction Consortium CPHT (comprising CFE, Besix, Dredging International, van Laere & de Meyer) TEC, through its partner Royal Haskoning, prepared the winning tender design. After the contract was awarded to the Belgium JV, TEC developed the detailed design for:

- All tunnel structures
- Two service buildings
- Detailed analyses of all transport and immersion stages; this included a risk-based analysis of the offshore transport of the tunnel elements and the buoyancy analyses for the tunnel elements of which some are double curved. Ballast exchange.
- Building pits for the approach and transition structures.
- Immersion trench
- Temporary works including the transportation and immersion equipment.

Also the towing design, model tests, joint design, temporary pre-stressing design as well as the failure risk analysis for the transport were provided.

Maliakos Gulf crossing, Greece

Project

The Maliakos Gulf Crossing is part of a 13 km road section for the motorway between Athens and Thessaloniki. The project comprises an immersed tube tunnel, with a length of around 4.5 km, crossing the Maliakos Gulf between the cities Hiliomili and Karavofanora.

Figure: Tunnel location

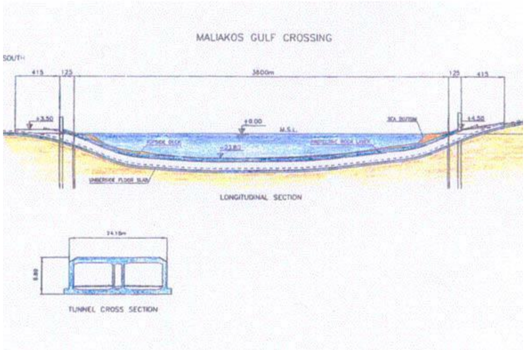


Figure: Schematic tunnel configuration

TEC's scope of work

For Ministry of Environment, Regional Planning and Public Works of Greece, General Secretariat of Public Works, TEC as part of the Maliakos Tunnel Consultant J.V. was responsible for

- Review of existing studies and recommendation for further studies.
- Technical and financial feasibility design for the tunnel.
- Pre-qualification.
- Preparation of tender document and technical specifications for a BOT contract and tender procedure.

Øresund Link, Denmark-Sweden

Project

In 1991 the Denmark and Swedish governments agreed to build a fixed link to connect the two countries across Øresund. The Øresund Link is 16.7 km long, and provides a direct traffic and train connection between Copenhagen and Malmö. The link consists of a peninsula with a length of 1km, a tunnel of 4 km, an artificial island of 4 km and a bridge of 7.7 km in length.

The tunnel is realised using the immersed tunnel method. The immersed part of the tunnel has a length of 3500 m and runs under the Drodgen Channel. The Øresund tunnel is the world's largest concrete immersed tunnel comprising 20 immersed elements. Each is 176 m long and is made up of 8 segments of 22 m each. The tunnel has two railway tubes, two motorway tubes and an escape gallery. The outer dimensions of the cross section are 8.5m by 41.7 m.

The tunnel element has been constructed in an innovative and exclusive manner, located about 10 km from the site, using an industrial method with 2 parallel production lines using the incremental cast & launch method. This method involves the casting of individual discrete segments on a fixed casting bed. After a minimum curing period the segment is pushed clear of the casting bed for match casting of the next segment on the same bed. Each segment was casted in a single pour (full section casting).

Figure: tunnel entrance & artificial island

The tunnel’s foundation consists of a gravel bed placed with high accuracy. For this purpose a special multi purposed pontoon was developed by the D&C contractor that allowed for the required high accuracy placement of the gravel bed (scrading method).

The safety of tunnel users was an important part of the design. Between the motorway tubes a central gallery is located that runs along the entire tunnel length with emergency exits at 88 m intervals. The tunnel is equipped with fire-protection material and state of the art tunnel installations and traffic management systems.

TEC's involvement in the project, in partnership with Øresund Link Consultants n.v., included the design, preparation of contract documents, tendering, supervision and monitoring of the detailed design and construction works for the tunnel, the artificial island, and peninsula.

Figure: Transport of tunnel element

TEC's scope of work

General
- Consultancy to the project Client Øresund Korsortiet

Civil
- Design of the immersed tunnel and tunnel approaches
- Preparation of the Tender documents and Technical Specifications
- Review of the Detailed Design prepared by the D&B Consortium
- Review of Construction Plans and Methodologies prepared by the D&B Consortium
- Construction Supervision

Dredging & Reclamation
- Design of the artificial island
- Preparation of the Tender documents and Technical Specifications
- Review of the Detailed Design prepared by the D&B Consortium
- Site Supervision

Chang Hong immersed tunnel, Ningbo, China

Project

The Chang Hong tunnel in Ningbo crosses the river Chang Hong. The crossing comprises an immersed tunnel section of 400 m in length and is made up of 4 elements each 100 m long. The tunnel width is 22.80 m and the overall height is 8.45 m.

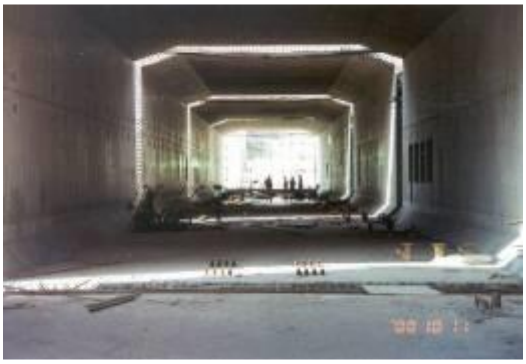


Figure: Tunnel elements under construction

TEC's scope of work

TEC, in association with the Municipality of Rotterdam, provided special design and supervision services to the Contractor STEC from Shanghai. These services focused on the immersed tunnel part.

Aktio – Preveza Crossing, Greece

Project

The work comprises a contractor design for a 600 m long tunnel. The immersed tunnel consists of 6 elements of 100 m with two tubes with double roads for traffic. The tunnel provides a connection through a bay of the Mediterranean between the cities of Aktio and Preveza in Greece. Special about the design was the impact on the design of the high risk of an earthquake in the area.

TEC's scope of work

TEC provided for the tender design.

Daugava river tunnel, Riga, Latvia

Project

The river Daugava divides the city of Riga in two parts, the west bank and the east bank. The city is a major seaport and a cultural and industrial centre with more than one million inhabitants. Due to economic growth the amount of traffic increased fast and the capacity of the existing river crossings is too low. To meet the expected traffic growth, a new Northern extension of the ring road was planned including a new river crossing with 2 x 3 lanes.

The Daugava Tunnel project is an 8 km highway link, starting at the east bank with an approach road of 2.250 m with several junctions and connections to the existing road network, an immersed tunnel part with a length of approximately 1.300 m and an western approach road of 4.500 m, also with several connections and crossings with the existing road network. A concrete immersed tunnel as well as a steel shell tunnel was designed.

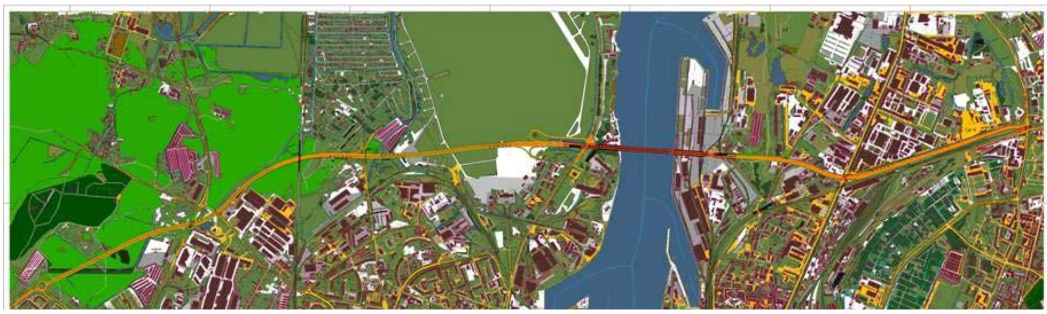


Figure: Tunnel alignment

TEC's scope of work

Design Engineer and Employer's representative for all the aspects of the project during the feasibility phase and the tender preparation phase, including:

- Quick scan of a high cable stayed bridge, bored tunnel and an immersed tunnel (concrete and steel).
- Preliminary design and Basis of Design for the immersed tunnel option.
- Employer's requirements for the Approach roads, the Tunnel Civil Structures, the Tunnel Electrical and Mechanical Installations. The Definition Drawings and the Quality System.

The design works included the following:

- Concrete immersed tunnel and approach roads, Casting basin, Cross overs.
- Dredging and reclamation works.
- Environmental aspects including contaminated soils.
- Approach roads, Viaducts and bridges, Alignments of all the roads.
- Electrical and mechanical installations.

Warnow Crossing, Rostock, Germany

Project

The Rostock Tunnel is a city tunnel crossing the Warnow River in the City of Rostock, connecting the eastern and western part of the town. The tunnel has two tubes, each comprising two lanes and a central wall. The total length, including approaches, is 1.500 m of which 800 m is enclosed. The immersed part consists of 6 tunnel elements each with a length of 120 m. The design of the tunnel is according to the German category B tunnel classification.

The project in Rostock is the first B.O.T. project in Germany.

Figure: Tunnel elements floating in construction dock

TEC's scope of work

During the tender phase TEC assisted the MDH consortium (Maculan, Dragados, Hegemann) with the technical proposal, delivering consultancy services regarding the overall tunnel design including the immersed tunnel and the casting basin.

During the construction phase TEC assisted the Warnowquerung Gmbh & Co. JV, led by the French contractor Bouygues Traveaux Publics. The main task of TEC was to review all documents concerning marine activities for the immersed tunnel. TEC is also leading in the supervision of those activities.

HSL tunnel Oude Maas, The Netherlands

Project

The high speed railway line section in the Netherlands runs from Schiphol Airport to the Belgium border towards Antwerp. For this railway a number of large civil works has been constructed including the crossing with the river Oude Maas. The enclosed part of the tunnel is approx.1.500 m.

The section below the river and the deep sections of the approaches are constructed using the immersed tunnel technique, with seven elements of 150 m each. The cross section comprises two tubes with one track each. The tunnel is suited for trains with a cruise speed of 300 km/h.

Figure: tunnel elements for crossing with river Oude Maas and Dordtsche Kil in construction dock

TEC's scope of work

Civil and structural:

- Reference design
- Tender documentation, tender evaluation
- Detailed design
- Structural calculations and drawings
- Geotechnical and geo-hydrological advisory
- Cost estimates and construction planning
- Supervision on the execution of the works

HSL tunnel Dordtsche Kil, The Netherlands

Project

The high speed railway line section in the Netherlands runs from Schiphol Airport to the Belgium border towards Antwerp. For this railway line a number of large civil works has been constructed including the crossing with the river Dordtsche Kil. The enclosed part of the tunnel is 1.500 m.

The sections below the river and the deep sections of the approaches are constructed using the immersed tunnel technique, with seven elements of 150 m each. The cross section comprises two tubes with one track each. The tunnel is suited for trains with a cruise speed of 300 km/h.

Figure: Crossing Dordtsche Kil

TEC's scope of work

Civil and structural:

- Reference design
- Tender documentation, tender evaluation
- Detailed design
- Structural calculations and drawings
- Geotechnical and geo-hydrological advisory
- Cost estimates and construction planning
- Supervision on the execution of the works

Thomassen (Caland)-tunnel, the Netherlands

Project

The extension of the A15 motorway to the so-called Maasvlakte crosses the Caland Canal. For this crossing a tunnel has been constructed with a total length of 1.500 m accommodating 2x3 road lanes and a service / escape duct. The tunnel is suited for the transport of dangerous goods (category I).

The tunnel was constructed to replace the bridge on motorway A15 that contained a movable part that opened 8.000 times a year to allow the passage of the sea-vessels.

The enclosed part of the tunnel is 1.100 m. The section below the canal and the deep sections of the approaches are constructed using the immersed tunnel technique, with six elements of 115 m.

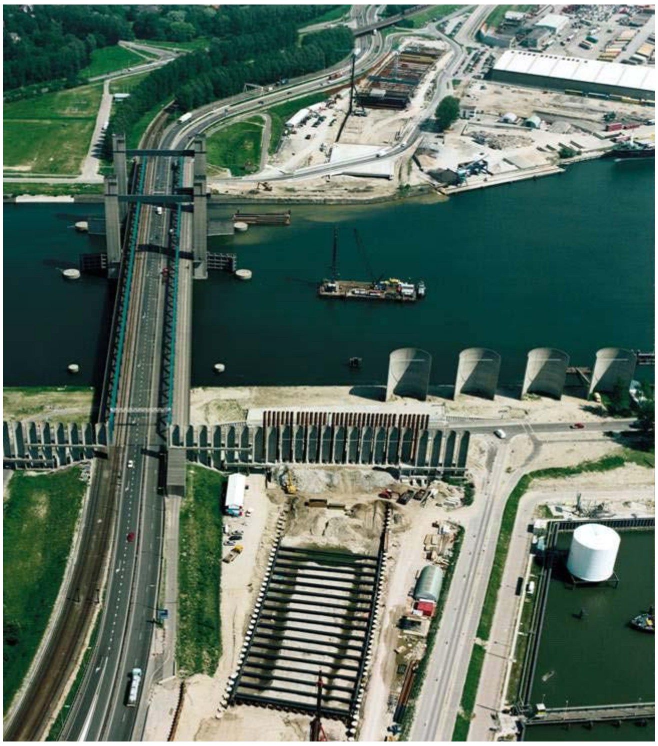


Figure: Tunnel under construction

Figure: Tunnel element during tow to site

TEC's scope of work

Civil and structural:

- Preliminary design and final design
- Structural calculations and drawings
- Geotechnical and geo-hydrological advisory
- Tender documents
- Cost estimates and construction planning
- Detailed design
- Advisory and supervision upon construction (in co-operation with the client)

Electrical and mechanical:

- Functional and design requirements
- Preliminary design and final design, including calculations, drawings and schemes
- Risk analyses
- Tender documents
- Cost estimates
- Review of contractors detailed design
- Monitoring and construction supervision

Thessaloniki Immersed Tunnel, Greece

Project

The project consists of a 3 km long road connection in the city centre of Thessaloniki. The crossing of the harbour comprises an immersed tunnel of 1200 m. The road accommodates a double three lane carriage motorway including emergency lanes. The region is subjected to seismic hazard.

The type of contract for the project is DBFOT.

The project includes access roads, cut and covers, immersed tunnel, technical installations and toll facilities.

TEC's scope of work

TEC provided the tender Design for the immersed tunnel, including casting basin to the Construction JV Bougyues / Alte / ASF / Volker Stevin.

Shannon river tunnel, Limerick, Ireland

Project

The Limerick PPP Scheme comprises approximately 10 km dual carriage way along with associated link roads and side roads. The scheme is linking the already constructed Limerick Southern Ring Road Phase I at Rossbrien with the N18 Ennis Road close to Shannon Airport. The Limerick PPP Scheme (Public Private Partnership) includes a fourth crossing of the River Shannon linking the northern bank with the southern bank at Bunlicky Lake.

The crossing comprises a 500 m immersed tunnel section constructed from five precast tunnel elements of a rectangular cross section for a dual lane in two bores. Further, the crossing includes 175 m cut and cover tunnels and 240 m ramps.

TEC's scope of work

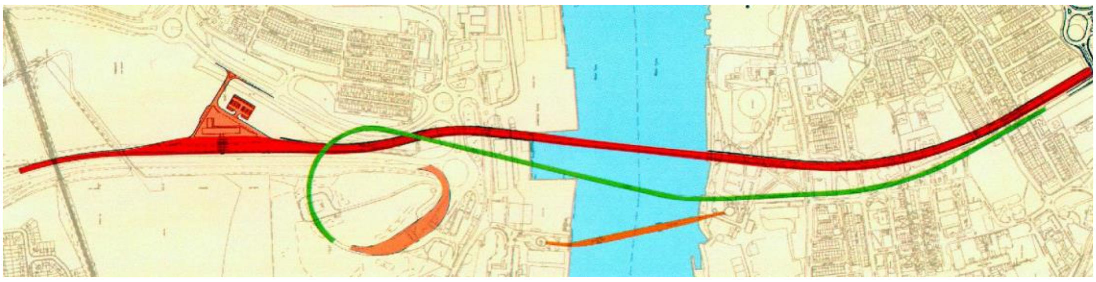
TEC has been, in cooperation with HPR, the designer for Bouygues who was one of the partners in a Contractors consortium bidding for the project. TEC provided design services in the tender phase of the project.

In the construction stage TEC assisted the specialist subcontractor of the winning consortium that was responsible for transport and immersion of the tunnel elements. TEC reviewed the transport and immersion design and all the associated immersion equipment.

River Tyne crossing, Newcastle, United Kingdom

Project

For many years serious congestion occurred at peak times on the A19 trunk road at its crossing under the river Tyne east of Newcastle. The bottleneck occurred in the 2 lane bi-directional Tyne Tunnel which was constructed as a bored tunnel (diameter 10.2 m and consisting of cast-iron segments) in the sixties of last century. In the reference design the existing tunnel will carry the northbound traffic (2 lanes), whereas the new tunnel carries the southbound traffic (2 lanes). The alignment of the new tunnel is mainly determined by the water depth and required depth in the navigation channel in the River Tyne and the crossing points over the existing tunnel in the northern bank.



The new crossing, comprising a 2 lane traffic tube and a 1.5 m wide escape/service tube, consists of:

- 380 m long immersed part at the river Tyne, 4 elements of approx. 95 m
- cut and cover tunnels south of approx. 800 m
- cut and cover tunnels north of approx. 320 m.

The new tunnel is required to cross the existing tunnel in two locations on the north side of the river. During construction of the new tunnel the existing tunnel will continue to be used. For reasons of protecting it is desirable to maximise the vertical separation between the two tunnels at the crossing points. This is the main reason why a 6% gradient is adopted at the northern approach of the new tunnel. Still the works required to construct the new tunnel must be carried out in such a way that the risk of disturbing loading conditions is minimised.

The Transport Authority appointed a consortium headed by Arup and including TEC partner Royal Haskoning to provide specialist advice for the proposed new crossing of the River Tyne, located adjacent to the existing Tyne tunnel.
The consortium advised the Tyne and Wear Transport Authority on all financial, engineering, legal and property matters involved. Royal Haskoning was responsible for all the civil and M&E related design services of the tunnel including an immersed section.

A Reference Design for the tunnel was prepared by Royal Haskoning which formed the basis upon which all necessary approvals and parliamentary powers to construct the tunnel were obtained. The tunnel was arranged to be constructed east of the existing bored tunnels between Jarrow and East Howden. It was proposed that the new tunnel would be built and operated by a Public Private Partnership (PPP) involving private firms who will join together as the Concessionaire.

The consortium was responsible for advising the Tyne and Wear Passenger Transport Authority on project definition, developing, the PPP project, Transport Works Act processes, Public inquiry, tendering process and the structure of the Concession Agreement.

Figure: Tunnel elements in the construction dock (ship yard in Newcastle)

TEC's scope of work (through mother company Royal Haskoning)

Civil & Structural:
- Reference Design of the immersed tunnel and tunnel approaches
- Preparation of the Tender documents and Technical Specifications
- Review critical items Detailed Design prepared by PPP Consortium

Dredging:
- Design of the dredged trench and associated hydrological and environmental studies
- Preparation of the Tender documents and Technical Specifications
- Review of the Detailed Design prepared by the PPP Consortium

M&E works:
- Reference Design for the tunnel
- Preparation of the Tender documents and Technical Specifications
- Review critical items Detailed Design prepared by PPP Consortium

Busan – Geoje Link, South Korea

Project

The Busan-Geoje Link Project provides an 8.2 km highway link between the southern city of Busan and the island of Geoje in South Korea which has been realised under a Build Operate Transfer (BOT) agreement.
The overall link comprises two major cable stayed bridges, with main spans of 230 m and 475 m respectively, and a 3.4 km long immersed concrete tunnel, located in a water depth of up to 40 m.

The immersed tunnel consists of 18 elements, each 180m long, 26.5 m wide and 10 m high. Each element consists of 8 segments each measuring 22.5 m. The tunnel accommodates 2 tubes for traffic (2 lanes each) and a central emergency / utility tube. The challenges for the Busan tunnel design included the difficult ground and foundation conditions, high water pressure and the seismic events. Another challenge was the adverse offshore conditions for the transport and immersion operation. The developments made in the field of transport and immersion of tunnel elements in this project increased the possibilities for immersed tunnels for sea crossings considerably. Special immersion equipment and state of the art working methods including advanced risk management was developed for this project by the specialist sub-contractor Mergor. In addition to the position of Technical Advisor to the Client TEC provided specialist support to the sub-contractor Strukton Immersion Projects for transport and immersion.

Figure: Tunnel element in construction dock

TEC's scope of work

As Technical Advisor to the, by the Concessionaire appointed Contractor responsible for the design, engineering and construction of the Link, TEC/Halcrow provided all technical advice, assistance, consultations and other consulting services required and/or desirable for the proper execution of the project and preparation, planning, design, construction and operation of the Fixed Link including, specifically, the immersed tunnel comprising among other things, an artificial island, and a cable-stayed bridge comprising, among other things, an approach bridge.

TEC/Halcrow was the Technical Advisor for all aspects of the whole of the project and during all project phases, for example preparation and construction periods, including:

- Cable stayed bridges
- Immersed concrete tunnel
- Dredging works
- Reclamation
- Approach roads
- Bored tunnels in hard rock
- Electrical and mechanical installations

- *Figure: Bridge – Tunnel transition*

The main advisory services have been as follows:

1) Preparation Period

(i) Design - Selection and Contract with the Employer for the Basic and Detail Designers including RFP preparation; Preparation of Design Standard and getting approval from the Authorities; Development of the Basic and Detail Design; Value Engineering; Coordination of the Design Team to ensure Workability and save Construction Cost

(ii) Implementation Plan

(iii) Selection and Contract with the Employer for the Design Checker and Supervisor including RFP preparation

(iv) Pre-casting yard for Immersed Tunnel and Cable Stayed Bridge) - Review for Propriety of Design and Construction of PC yard
(v) Consortium related - Cooperation Agreement; Construction Contract;
(vi) Preparation for Construction - Site Organization for Construction; Progress Schedule of the Project; Working Method; Equipment for the Construction; Preparation of check points of main work items; Selection and contract of outside (international) subcontractor including bidding work; Procuring of equipment and material.

2) Construction Period
(i) Design - Design Management System; Design Review before Construction; Review of Design Change items and Presentation of proper Alternative; Value Engineering
(ii) Construction - Site Construction Management System; Construction Plan and programme; Working Method for each work items, Equipment and Manpower to be used; Process Management; Quality Control; Safety Management; Cost Saving; Selection and contract of outside (international) subcontractors including RFP preparation; Procuring of equipment and material.

Coatzacoalcos tunnel, Mexico

Project

Coatzacoalcos is a port city in the southern part of the Mexican state of Veracruz, on the western bank of the Coatzacoalcos River. The city has a population of about 250.000, making it the third-largest city in the state of Veracruz. The largest community in the municipality, aside from Coatzacoalcos, is the town of Allende, with a population of about 25.000. The town of Allende is situated on the east bank of Coatzacoalcos River.
The city's industry is dominated by the petrochemical sector. The main petrochemical complexes are however located on the east bank of Coatzacoalcos River and can only be reached via an old and heavily congested bridge south of Coatzacoalcos.

To improve mobility, the State Government of Veracruz has entered into a Construction, Operation, Maintenance and Exploitation Contract for an immersed Tunnel under the Rio Coatzacoalcos. The tunnel accommodates 2 tubes, each suitable for 2 traffic lanes separated by an escape tube.

The immersed tunnel will be constructed out of 5 tunnel elements of 138 m each, resulting in a total length for the immersed section of 690 m. At both ends of the immersed tunnel, access ramps will be made by the cut & cover method using diaphragm walls. The water depth of the Coatzacoalcos River varies between 5 and 12 m. The maximum depth of the base of the tunnel will be about 30 m below water level.

Figure: Tunnel elements under construction

TEC's scope of work

TEC provided the following design services for the Spanish-Mexican construction consortium CTC, headed by FCC from Spain:

- Quick Scan
- Tender Design for the complete link (immersed tunnel and approaches).
- Detailed Design for the immersed tunnel including all related temporary structures/works.

Immersed Tunnels in North/South Metro line, The Netherlands

Project

To relieve the existing public transport system (bus, tram, metro and ferry lines) in and around Amsterdam, the existing metro system will be complemented by an additional 5th line: *the North-South line*. The new line is expected to provide transport for approximately 200,000 people a day. The 1st part of the line extends from the A10 ring road in Amsterdam North to the A10 ring road in Amsterdam South and has a length of 9.5 km. In a later stage, the line may be extended to the north, in the direction of Zaandam and to the south, in the direction of Schiphol International Airport.

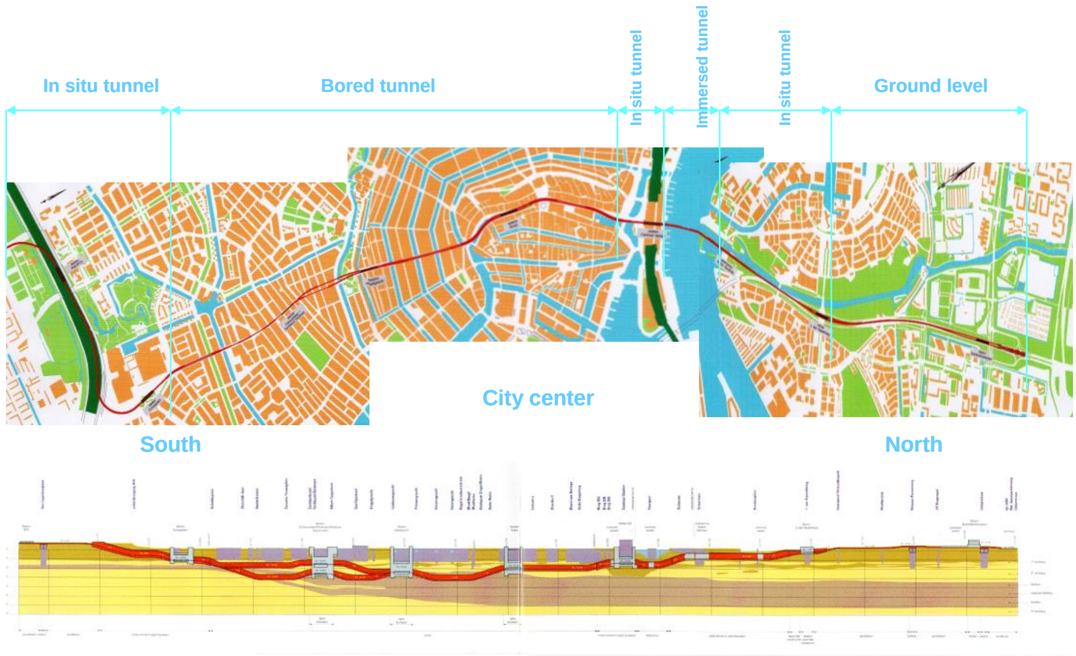


Figure Plan view and elevation of new metro line

The line will be realised on ground level in the southern and northern parts, by way of an immersed tunnel where it crosses the river IJ, and by means of a 3.4 km long double tube bored tunnel to cross the old city centre. Several sections of the metro line will be made by applying the conventional cut-and-cover technique, as well as by the less frequently used caisson-technique. Three new stations will be realised on ground level, one station will be built underground beneath an existing railway station, three deep underground stations will be constructed in the city centre, and one underground station at a relatively shallow depth. An innovative design approach containing special construction techniques was required, especially for the four stations in the city centre.

TEC's scope of work

As the Lead Consultant for the Client, the Municipality of Amsterdam, the TEC partners were responsible for the integral design (involvement since 1994). During the initial stages, the Reference Design was developed, followed by the pre-design, final and detailed designs, drawings and technical specifications, tender documents, consultancy regarding the contracting strategy, contract administration, construction supervision, as well as the preparation of

procedures and guidelines for project monitoring, assistance with the public consultation and permit process, risk management, construction safety and environmental issues.

Project Immersed tunnel under the IJ-river

The North/South Metro Line crosses the IJ-river by means of an immersed tunnel. The immersed part has a length of approx. 425 m and consists of three elements of 142 m. The two track metro tunnel is 11.25 m wide and 7.55 m high. The northernmost element is partly located in the IJ embankment and subjected to a high ground load. At the south end the immersed tunnel has very poor soil conditions.

The tunnel elements were constructed in the building pit of the northern approach. After completion the building pit was flooded, the tunnel elements were floated up and transported to the Suez Harbor in the western Amsterdam Port. The elements were moored for 4 years to wait for the completion of the northern approach and the metro station Central at the south end. The tunnel elements were immersed in autumn 2012.

The northern approach was constructed using conventional cut & cover techniques.

Figure: floating transport of tunnel element

TEC's scope of work

The consultancy services included:

- Feasibility study in which the immersed tunnel was compared with the bored tunnel.
- Pre-design, final design, tender design and detailed design.
- Tender documentation and consultation.
- Contract management and supervision.

Crossing under Amsterdam Central Railway Station

Project

A major challenge for the realization of the North/South metro line station "Central Station," is its passage with the historic railway station. The platforms for the metro station are located directly under the railway station. The boundary conditions for the design of this station were very stringent since the railway station had to remain in full service during construction in terms of train operation and maintaining the traveller flows. In realizing this passage, a combination of the wall-roof method and the immersed tunnel technique is used. In this way parallel construction was possible and the construction activities at the railway station could be limited.

Innovative building pit concepts were used for this passage. A tailor made sandwich wall, a combination of two rows of steel piles and jet grout columns and a micro tunnelling wall was developed especially for this project. The walls were capable to absorb horizontal and vertical loads. A deck structure supported by the walls was constructed in various stages and carries the part of the railway station above the building pit.

The platform section of the station is installed using the immersed tunnel technique. The 136 m long tunnel element is constructed in a construction dock opposite the river IJ and floated to its final location underneath the railway station, and immersed under very limited headroom and in several stages, using new developed techniques.

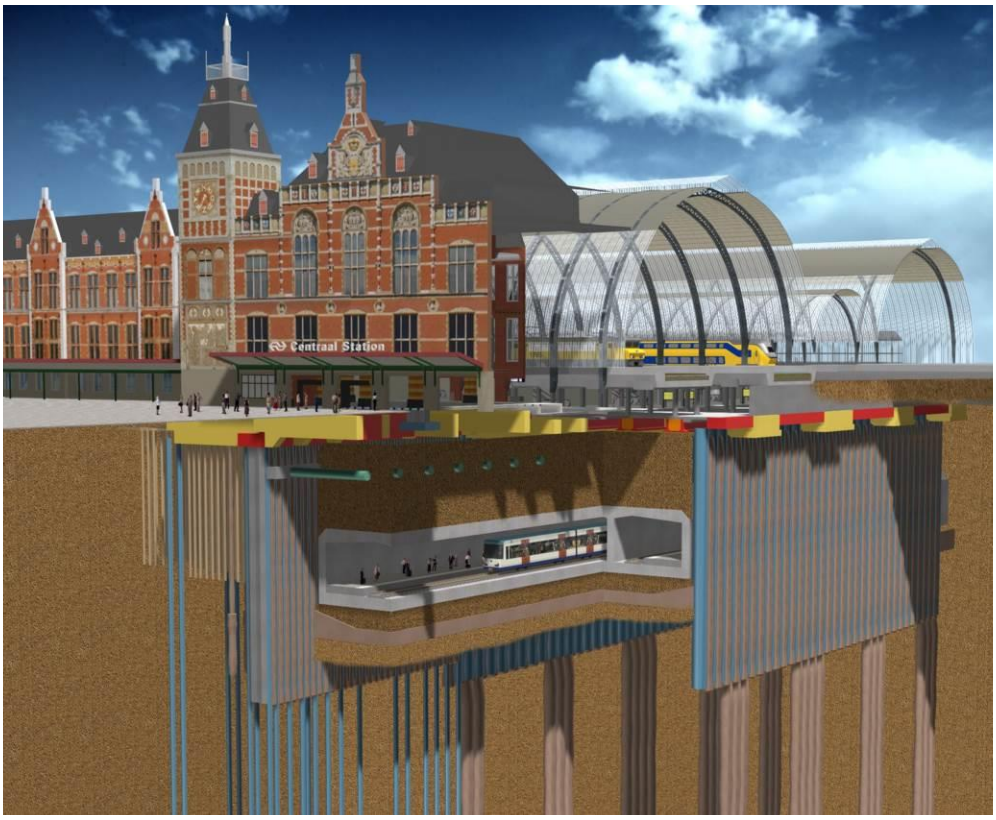
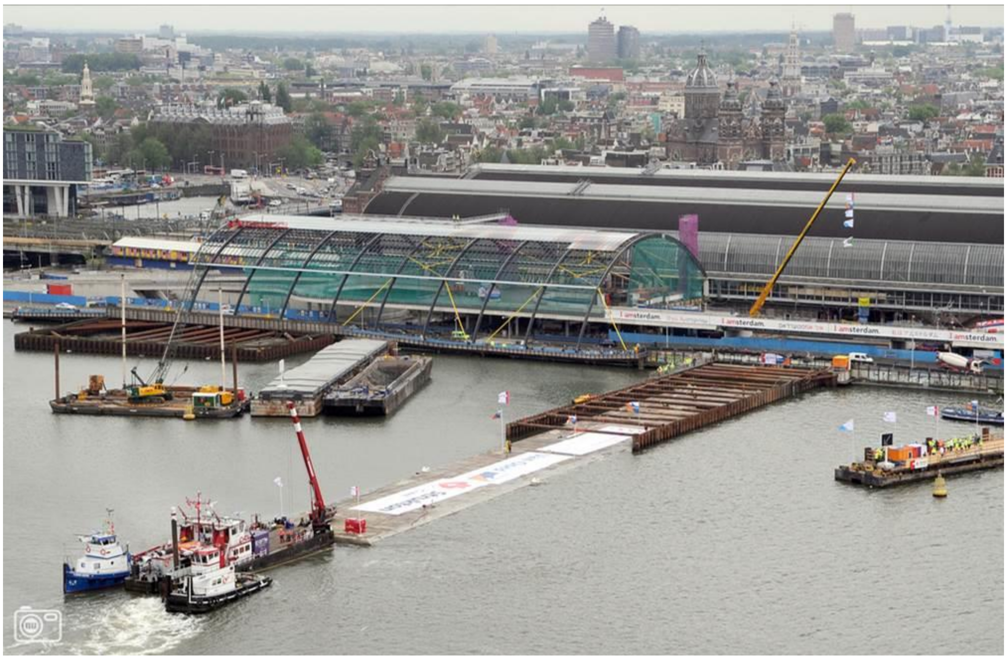


Figure: Illustration of the immersed tunnel under Amsterdam Central Station

TEC's scope of work

The consultancy services included:

- Technical studies after building pit concept to construct immersion pit
- Pre-design, final design, tender design and detailed design
- Tender documentation and consultation
- Contract management and supervision
- Alliance steering group management for the construction of the innovative building pit walls



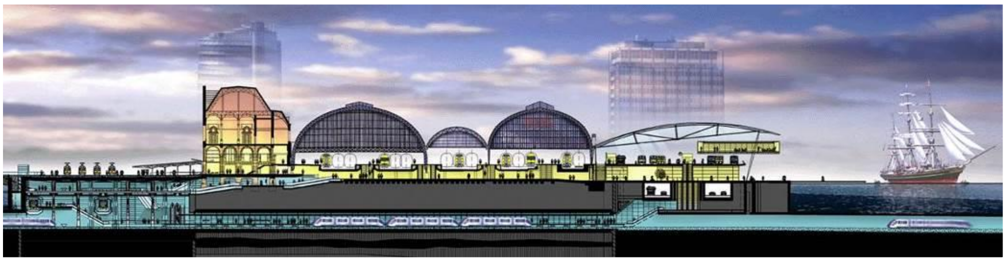


Figure : *Transport of tunnel element under Central Station (top figure)*
Section of new transport hub (metro -2 and -1), railway (0 and +1), bus station (+1) (bottom figure)

2nd Coentunnel, Amsterdam, The Netherlands

Project

The A10 motorway is crossing the Noordzee Canal on the Western side of Amsterdam. The traffic capacity of the existing Coen tunnel, built in the sixties is insufficient with major traffic jams during the daily peak hours. Therefore on the east side of the existing tunnel a second one is planned with 2 additional tubes.

The enclosed tunnel section of 640 m crossing the canal is designed as an immersed tunnel. The immersion trench required additional attention since the existing tunnel was relatively close by; retaining structures were included in the design to achieve a limited and acceptable impact to the existing tunnel.
For the approaches of approximately 150 and 200 m various construction methods were studied. For the Southern approach the pneumatic caisson method was studied in detail, to ensure that the companies with vibration sensitive production can continue their business at all times. The Northern approach was designed as a concrete structure built in a pit with temporary sheet piles and an under-water concrete slab with tension piles.

Initially a contract was prepared for a conventional bid-built contract. Later the Client decided to go for Design Built Finance Maintain contract, for which the contract documentation was prepared as well.

TEC's scope of work

The consultancy services for the Dutch Public Works included:

- Technical studies
- Tender design for conventional Bid-Built Contract
- Preparation of tender documentation and BoQ for a conventional Bid-Built Contract
- Preparation of tender package for DBFM contract and management during tender procedure

Oosterweel tunnel, Antwerp, Belgium

Project

The Oosterweel Link is an important project. This closure of the inner Antwerp ring road (R1) extends over a length of approximately 10 kilometres and forms the link between a new R1 (Kennedy Tunnel) – E17 – N49 traffic interchange, which has yet to be constructed; on the left bank via a new Scheldt cross-river connection (Oosterweel Tunnel) and an Oosterweel junction on the right bank, with the R1 (Merksem Viaduct) – E19 – A12 on the right bank.

The works on the left bank include two flyovers, several multi-level intersections, sewers and landscaping. Furthermore, during the tendering phase a toll plaza on the left bank had to be fitted into the traffic scheme.
The tunnel under the Scheldt has 2 x 3 lanes plus a cyclist tunnel and a service tunnel. The overall width is about 44 m and the total length is 2650 m. The tunnel consists of an open access section 445 m long, cut & cover sections on both banks of 405 m and 450 m, and an immersed tunnel 1350 m long.

Figure: Rendering of the new interchange and southern entrance of the tunnel

TEC's scope of work

TEC partner Royal Haskoning provided the geotechnical, civil, and structural design as well as all roadway engineering for the works on the left bank and the tunnel for Noriant-DC, a Belgian construction consortium. In addition, Royal Haskoning provided all of the tunnel's technical installation engineering.

Hong Kong – Zhuhai – Macau Link, China

Project

The Hongkong Zhuhai Macao Bridge Link (HZMB) can be considered as one of the most challenging infrastructural projects to date. The Link comprises various bridges, causeways, artificial islands and tunnels. The full HZMB project measures over 50 km in total.

The Main Bridge offshore section has a length of approximately 30 km and includes a 6 km immersed tunnel (at completion the worlds' longest) with 2 artificial islands on either side to accommodate the transition to the bridge part that runs towards Hong Kong and Macau / Zhuhai. The bridge part of the Main Bridge section includes various box-girder and cable-stayed bridges. The Link will carry a three-lane dual carriageway with a design speed of 100 km/h and is designed for a 120 year design life.

Figure: Rendering of the Link

Tunnel design

The immersed tunnel is constructed in reinforced concrete and one of the most challenging parts of this project. The structural design of the immersed tunnel is determined by various boundary conditions. Since the tunnel has to carry a three lane dual carriageway, the roof spans are relatively large with 14.55 m. The tunnel is placed 30 m below sea level (roof level) and deep under the existing seabed to allow for the future deepening of the shipping channel to accommodate passage of 300.000 tons vessels. Until this future deepening the immersion trench is allowed to fill with sedimentation up to the existing sea bed, resulting in a ground cover on the tunnel of over 20 m.

The geotechnical conditions at the project location are unfavourable and have a significant impact on the immersed tunnel design. Although the immersed tunnel can be applied in relatively poor soil conditions additional measures are required

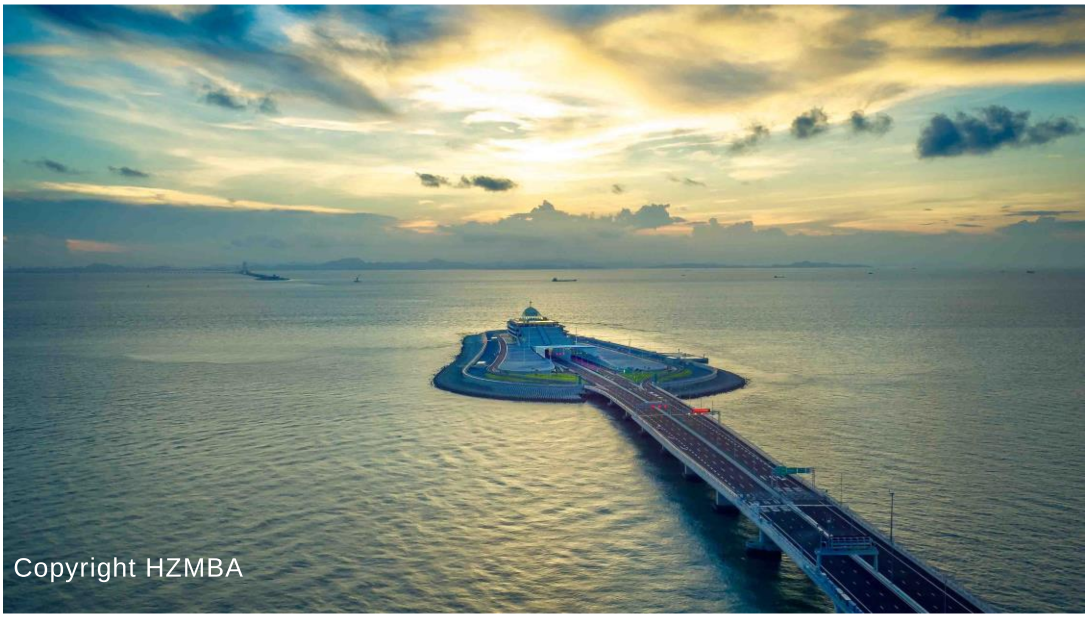
especially in the shallow part of the immersed tunnel. To limit settlements sand / gravel replacement and sand compaction piles with a replacement ratio up to 70% have been used. For the transition between the immersed tunnel and the existing soil a gravel bed is used.

Transport and Immersion

The immersed part consists of 33 tunnel elements with a length of 180 m. With the cross sectional dimensions of 11.5 * 37.95 m the elements will be the largest concrete tunnel elements in the world. The tunnel elements are built in a construction dock located at some 10 km of the project site, and are transported and immersed under offshore conditions.

Artificial Islands

At the transition from the tunnels to the bridge parts artificial islands are constructed. The land reclamation for these islands is carried out in relatively soft soil conditions. For the design the very soft top layers are replaced by sand; the underlying soft layers are treated with sand compaction piles. Large steel cylinders (diameter 20 m, height 40 m) are used to create the perimeter of the island. After the installation of these cylinders the area was filled with sand thus creating the island. On the islands cut &cover tunnels are constructed which connect to the immersed section.



TEC's scope of work

In this project TEC holds the position of Client Consultant for the HZMB Authority and has provided consultancy and review services for the immersed tunnel, cut and cover tunnels and the artificial islands during the design and construction phases.

Services:

- Review of HZMB Special Standards that covered the Design, the Construction, the Operation & Maintenance and the Quality Control for the project. The review had to ascertain that these Special Standards were not only in compliance with China, Macau and Hong Kong Codes and Standards but also state-of-the-art from an international perspective.
- Review of the Conceptual Design, to ensure the accuracy and rationality of the design and related studies and research results.
- Review of Preliminary, Final design to confirm before entering the tender and procurement stage. In this stage TEC prepared the technical specifications and assisted the Client in the compilation of the tender documentation for the first large D&B contract in China.
- Review of Detailed Design and Consultancy during Construction phase. TEC is supposed to bring in the specialist expertise regarding interaction between immersed tunnel design and construction and knowledge about critical details (ongoing).
- CPT-U special study to introduce in China the use of cone penetration tests as an economic way to explore ground conditions (study was performed for HZMB project).
- (detailed) parallel analyses (special studies) to confirm the detailed design on critical issues, such as the longitudinal design including joint design, seismic analyses and cross section structural analyses.

Fehmarnbelt immersed tunnel, Denmark-Germany

Project

The Fehmarnbelt Fixed Link will be the third major fixed link in the Danish Road Network and will serve as a direct road and rail connection between Scandinavia and continental Europe. The Fehmarnbelt Fixed Link will specifically connect Rødbyhavn in Denmark to Puttgarden in Germany and is expected to bring economic benefits to the entire region around the Fehmarnbelt. The opening of the Fehmarnbelt Fixed Link will significantly reduce the travel time between continental Europe and Scandinavia and eliminating the time spent on embarking, disembarking and waiting for ferries.

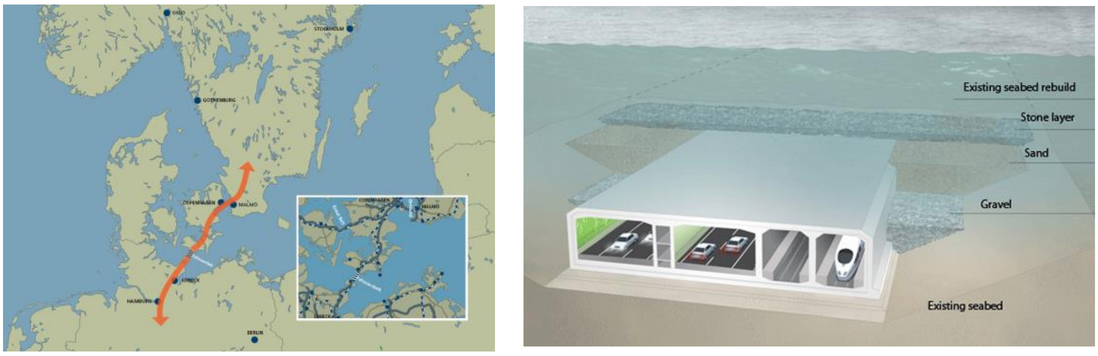


Figure: Tunnel location and typical cross-section

In a feasibility study carried out the cable stayed bridge was selected as the preferred option for this approx. 20 km long fixed link. The immersed tunnel option was identified as the best alternative.

From 2009 the selected bridge and tunnel option were investigated and compared in more detail in a true design competition. These designs are undertaken by separate groups of consultants commissioned by the state owned organization Femern A/S (Client). The two designs were prepared in isolation and it was the intention to select one of the options for further development. The immersed tunnel option design was assigned to the RAT JV, comprising TEC, Arup and Rambøll. After a design period of approximately 2 years the JV submitted an integral state of the art immersed tunnel design. In February 2011 the immersed tunnel option was selected by the Client as the preferred option to realize the fixed link between Germany and Denmark.

After the immersed tunnel option was selected, detailed documentation was prepared for the German plan approval procedure and those for the German and Danish environmental impact assessments. The plans are made available to the public and for interested parties to comment. In parallel with the permitting procedure, further detail was put on the bones of the project and the Client was assisted in the preparation of the tender documentation. The tender process started late 2013 using the principle of a competitive dialogue during which shortlisted construction consortia are challenged to introduce innovative and competitive ideas. The project will be divided into a number of procurement packages, including Immersed tunnel North and South, Dredging and Reclamation, Portal and Ramps and tunnel systems. If everything runs according

to plan, the construction will start in 2015 and the tunnel will be open for traffic in 2021.

The Fehmarnbelt Link is special in a number of ways, but especially the length of the tunnel stressed the Designers to come up with innovative and advanced design concepts in order to “beat” the bridge option. An integral design approach was essential to come up with a balanced, competitive and above all safe solution. The challenges of Fehmarnbelt tunnel are summarized below:

- Since no Code or Regulation is covering the design of a 19 km tunnel a special state of the art safety concept had to be developed and agreed with the Authorities of Germany and Denmark (including ventilation concept and advanced traffic management and information systems).
- A construction planning of maximum 6 years required a further extension of existing construction techniques (factory method using cast & launch principle).
- An economic but safe cross section had to be developed.
- A tailor made operational and maintenance strategy was developed using special tunnel elements accommodating operational and maintenance features and guaranteeing maximum availability of the Link during operation.
- To reduce the environmental impact the project objective was to achieve a closed ground balance. Dredged material was used for land reclamations on the Danish and German side (landscape design), that were developed into ecological zones.

TEC’s scope of work

TEC plays a key role in the JV RAT design team to develop the Integral Immersed Tunnel option. E.g. from 2009 mid 2011 and from December 2012 – to date TEC held/holds the position of the Project Manager of the RAT JV.

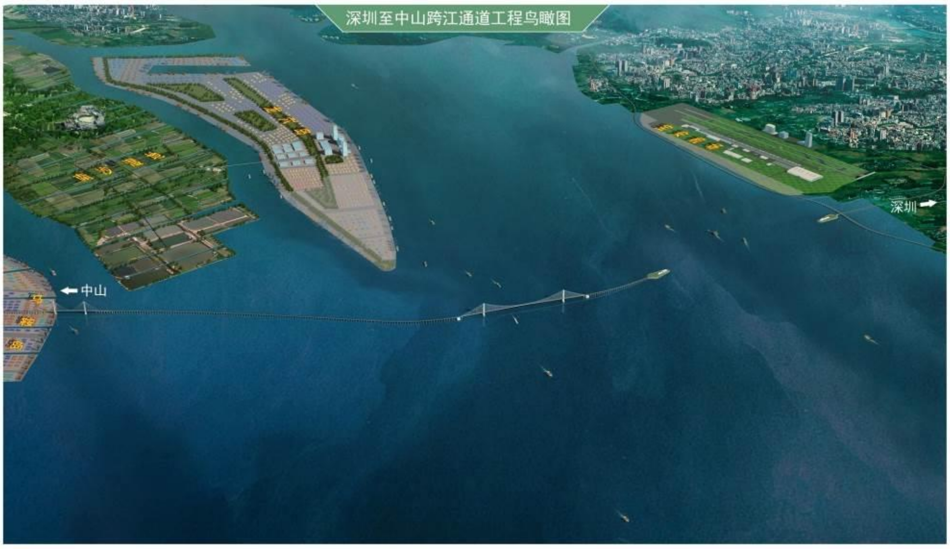
The Tunnel Design services comprise:

- Conceptual Design (completed)
- Plan Approval Design (completed)
- Tender / Illustrative Design (completed)
- Assistance in preparation of tender documentation (completed)
- Assistance in prequalification process and evaluation (completed)
- Assistance during the (preparation of the) Competitive dialogue (ongoing)
- Tender Evaluation
- Review of Basic / Detailed Design of selected Construction Consortia
- Monitoring and Supervision of construction works

Shenzhong crossing China

Project
The Shenzhen-Zhongshan link is located in the Pearl River Delta, approx. 40 km north to the Hong Kong Zhuhai Macau Bridge (HZMB) and connects the Shenzhen Economical Special Zone with Zhongshan and Jiang-Men in the Guangzhou area.

This link is supposed to carry 2 x 4 traffic lanes and has a length of about 50 km and of which over 20 km is under marine conditions. The marine section of the project is considered to be the most challenging in which the selection of the appropriate alternative and associated technical solutions was extensively studied by both a local Chinese Design Institute and in parallel by an international consultant (awarded to TEC).



TEC's scope of work
For this project a parallel study was carried out on a conceptual design level that focused on the 20 km marine section including the main navigation channels, Fan-Shi and Ling-Ding channels.

In the study several options were studied and compared, as follows:
(1) Full Bridge from East to West
(2) Two Bridge-Tunnel options
(3) Full Tunnel from East to West)

For the tunnel sections, the immersed tunnel, bored tunnel and mined tunnel construction methodologies were compared for each of the above tunnel sections, where the lengths varied between approximately 6 km and 21 km. In addition the dimensions of the artificial islands appeared to be a critical issue from a hydraulic blockage perspective. Apart from the civil works aspects, tunnel safety and associated ventilation concepts played a dominant role in the studies.

Söderström, Sweden

Project

The tunnel in the Söderström is part of the Citybanan project and comprises a 340 m long immersed tunnel which is located between Riddarholmen and Södermalm. The immersed tunnel will be part of a 6 km long tunnel with two railway tracks and connects the rock tunnels at either side of Lake Ridderfärden. The Söderström tunnel consists of three prefabricated tunnel elements, two short cut and cover tunnels and a joint house. Unique for Europe and due to the limited water depth the immersed tunnel is constructed as a sandwich tunnel with concrete and a double steel shell. The tunnel is placed partly above the lake bed on 3 pile groups due to the soft soil on top of the bedrock. After the immersion operations the three tunnel elements will be connected by means of prestress. The tunnel will be fixed at the southern end in the rock at Södermalm and has a free end at the joint house (at the northern end) where movements can take place.

TEC's scope of work

- Review of the immersion process plan and all related documents which are prepared by the Contractor.
- Supervision / observations on behalf of the Client during the immersion operations.

Santos-Guarujà Crossing, São Paulo, Brazil

Project

The project is located in the Port of Santos, between the two cities Santos and Guarujá in the state of São Paulo coast, some 80 km southwest of the city of São Paolo.

The two cities are separated by an approx. 500 m wide entrance channel to the busiest port of South America. The connection between the cities is currently operated by ferry boats, but there is a desperate need for a fixed link to accommodate the increasing transport volume and regarding the foreseen extension of the harbor as a consequence of the economic growth. The realization of a fixed link will reduce the current travel distance on the road from approx. 45 km to less than 1 km.

An immersed tunnel has been selected by the government as the most viable option to establish a fixed link between the two cities. This option, the first of its kind in Brazil, combines a safe and secure connection with least impact on city life and port development against a reasonable investment. TEC has provided consultancy for the selection process.

The tunnel will consist of an enclosed section of about 760 m and approaches, all-in-all some 1,800 m length. The harbor channel depth is up to 21 meters to allow for deeper draft vessels to enter the port area. The tunnel will consist of 2x3 lanes for road traffic and a separate tube for pedestrians and cyclists.

TEC's scope of work

TEC's involvement consists of three parts:

Knowledge transfer

As this is the first immersed tunnel to be constructed in Brazil, there is a requirement to build knowledge about this technology in the country. TEC will contribute by writing a design and execution manual, specifications with regard to construction and operation & maintenance manuals. Such documents are to be used by local partners for this project.

Design review

The project will be designed by local Brazilian consultancies. With regard to the specific immersed tunnel aspects, TEC will review the designs and propose improvements.

Design management

As part of the project management team of the Client, TEC is managing the design process. This is being done by having permanent presence in São Paulo by the general design coordinator. On top of that experts are participating in the design management process on topics like:

- Geotechnical engineering;
- Tunnel safety;
- Tunnel element transport and immersion process;
- Construction site selection and preparation;
- Structural engineering;
- Traffic and alignment engineering;
- Cut&Cover and tunnel approaches design.

Sharq Crossing Doha, Qatar

Project

Conceived by world renowned Architect and Engineer Santiago Calatrava on behalf of the State of Qatar’s Public Works Authority ASGHAL, the unique 21st century bridge-tunnel connection across Doha Bay comprises three bridges, two immersed tunnels with a total length of approx. 6 km and three cut-and-cover tunnels.
Tunnel Engineering Consultants (TEC), together with Santiago Calatrava Engineers and Architects worked on the validation of the original concept design of five tunnels that are part of Qatar’s new landmark Sharq Crossing.
This is one of the most iconic and prestigious bridge-tunnel connections TEC has been commissioned to work on to date, and the first ever immersed tunnel project in the Middle East region. Of particular interest is the Marine Interchange as a complex underground interchange, connecting the two immersed tunnels and the West Bay Bridge. Also the West Bay Bridge will have the world’s largest arch span connecting the shore with the Marine Interchange.

Background

The approx. 12 km bridge-tunnel connection Sharq Crossing is a vital part of the Greater Doha Transportation Master Plan. In recent years the city of Doha has seen considerable increase in population, car ownership and new city districts. It is forecast that the area will experience serious traffic problems in the near future.
The project was supposed to be completed in 2020, at which point the Sharq Crossing would link the new Hamad International Airport with Doha’s city centre and new city and business districts. It would also help Qatar receive all visitors to the 2022 FIFA World Cup events. Unfortunately the project was put on hold in 2015.

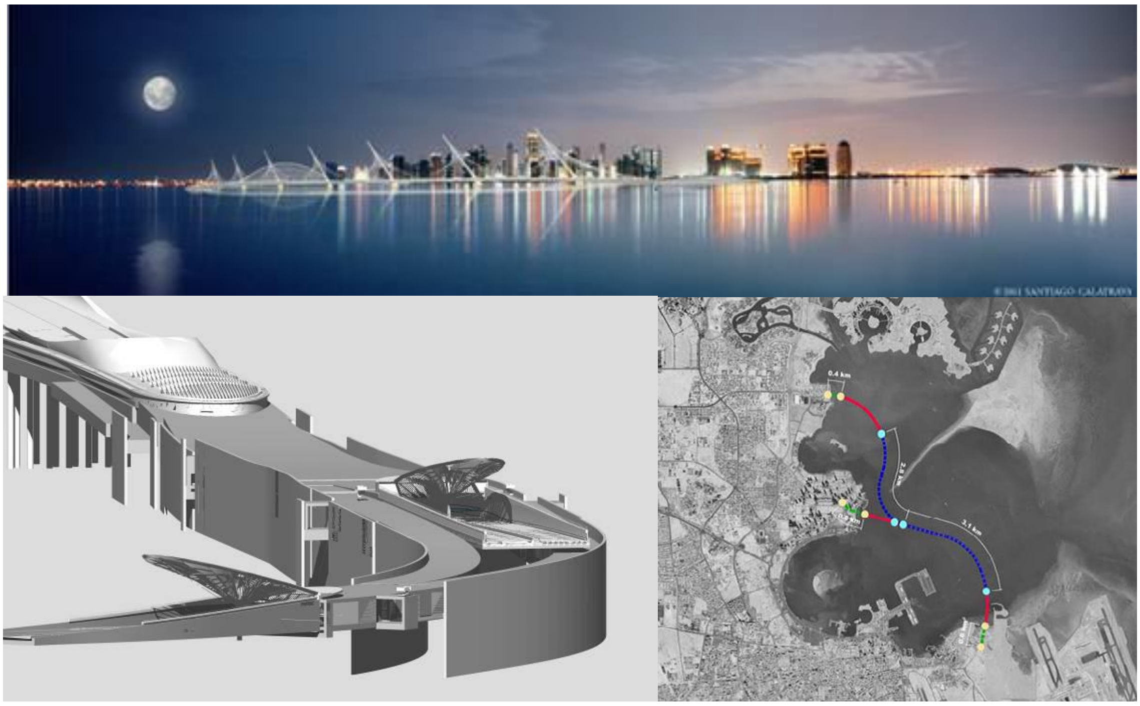


Figure : Renderings and plan view of the project

Scope of work

TEC prepared the validated Concept Design of the two immersed tunnels of 3.1 and 2.8 km, the three cut-and-cover tunnels with a length of approx. 950-1250 m each connecting the bridges to the mainland and the Marine Interchange of approx. 600 m, connecting the two immersed tunnels and one of the bridges.

The assignment also included the design of bridge foundations, roads, utilities, mechanical, electrical and plumbing (MEP) systems, the integral safety concept including ventilation and construction schedule.

TEC worked together with HBI Haerter Ltd. (Zurich, Switzerland) for safety and tunnel ventilation and Geotechnical Consulting Group (GCG; London, UK) for geotechnical expertise.

The recent sub consultancy agreement covered the first project phase: Concept Design Validation. TEC has executed the first phase in 5 months time, which started in September 2013 and was completed by January 2014.

Figure : Interior of the tunnel

Marieholmstunnel, Gothenburg, Sweden

Project

The Marieholm Tunnel in Gothenburg is a road tunnel with three lanes per direction and a central gallery. The tunnel consists of an immersed tunnel section with cut & cover tunnel and open ramp sections at both ends. The immersed tunnel section crosses the Göta Alv river, measures 306m in length and is made up of 3 tunnel elements of equal length.

The tunnel elements will be fabricated in a construction dock at the Marieholm-side of the crossing, within the alignment of the tunnel. The construction dock has room for a single tunnel element which requires the dock to be used 3 times for the IMT after which the cut & cover tunnel can be realised at that side of the crossing.

The tunnel elements will be segmented and will be placed in a dredged trench on a sandflow foundation.

TEC's scope of work

Permanent civil works for the immersed tunnel section of the project:

- Preliminary Design
- Final Design
- Detailed Design

ShenZhong Link International Design Competition, China

Project

The People’s Government of the Guangdong Province plans to build a sea-crossing link between Shenzhen and Shongshan. This Shen-Zhong Link is located about 30 km to the south of the Humen Bridge in Guangzhou and about 38 km to the north of the Hong Kong-Zhuhai-Macao Bridge Link.

The new link will shorten the commuting distance of two economic circles sitting on the east and west shores of the Pearl River. The link is not only a corridor for Shenzhen and Zhongshan, but is also for strategic importance to the Nansha, Qianhai, Cuiheng and Hengqin areas of the city of Guangzhou, Shenzhen, Zhongshan and Zhuhai respectively. Upon completion of the link, the travel time from Shenzhen to Zhongshan will be significantly reduced, from more than two hours to twenty minutes in clear traffic.
The connection has a length of 24 km, has 4 lanes in both directions and starts at a new artificial island south of the Shenzhen airport where the link is connected with the Guangzhou-Shenzhen Riverside Expressway. From there it passes underneath the Dachan waterway, the Airport Secondary Fairway and the Fanshi Waterway with a tunnel. At the West Artificial Island the tunnel switches to a bridge crossing the Lingdin West Fairway and the Hengmen East Waterway with a suspension bridge, approach bridges and a cable stayed bridge. At the Hengmen Interchange the link is connected with the Zhongshan-Kaiping Highway.

The immersed tunnel possesses 2 traffic tubes and a central gallery with a total width of 46 m and a length of 5.25 km. For the deep sections, reaching water depths of 35 m, full steel sandwich elements turned out to be most economical. For the less deep and wider sections single shell elements were proposed. As this will be the first full steel tunnel in China the cross-sections were developed in detail. An overall construction schema was set up and a casting basin for production of the tunnel elements on the Shenzhen side of the river was selected. The geology along the alignment was analysed from which the dredging methods for the trench were selected. For a number of hard spots along the alignment soil treatment like sand compaction piles and soil replacement were advised.

Besides being a transition between the tunnel and the bridge also recreational functions were assigned to the island and the entrance to the tunnel was turned into a landmark. For land formation of the main body of the artificial islands large diameter steel cylinders with rock revetment in front are proposed. Settlement and stability is controlled through soil replacement, vertical drainage and dewatering of the main island body and through sand compaction piling underneath landscaped rock revetment.

TEC's scope of work

TEC, in combination with the Guangdong Highway Reconnaissance Planning Design Institute and Information Based Architecture, prepared a set of design documents covering all aspects of the tunnels, islands and bridges.

The TEC, GDDI and IBA joint venture ended second in the competition. The client amongst others valued the technical depth of the study and the practical knowledge and experience brought in from other large tunnelling projects.

The TEC scope of services covered the integral design of the immersed tunnel and the artificial islands. The following items were prepared by TEC and were included in the competition documents:

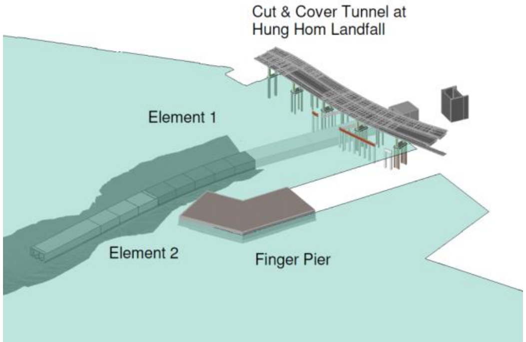
- Architectural design and landscaping
- Structural safety and foundation design
- Mechanical and electrical installations
- Life safety
- Construction methodology and schedule
- Construction cost estimate

Shatin to Center Link, contract 1121, HongKong, China

Project

The Shatin to Center Link is a new to build subway line between Shatin station on Kowloon Island and HK Central station on HongKong Island. Contract 1121 consists of the connecting Cut and Cover tunnels at Hung Hom Station and the Causeway Bay Typhoon Shelter, and in between an immersed tunnel with a length of 1.3 kilometres suitable for 2 track metro. The tunnel elements will be built in a construction dock (Shek'O) at the south side of HongKong Island and transported to the site in the Victoria Harbour. The Client is MTR, the public transport company of HongKong.

Tender process in a competitive dialogue with the Client and in two stages: 1st Stage submission is a technical bid and 2nd Stage submission is a financial bid and updated technical design.



TEC's scope of work

TEC has been working together with MottMacDonald HK as a sub consultant for the Contractors' JV consisting of Zublin (Germany), Samsung (South Korea), Strukton (The Netherlands) and Hsin Chong (HongKong).
TEC was responsible for the design of the immersed tunnel; the baseline design and several alternatives resulting in an Innovative Design.

TEC Deliverables for the Tender Bid:

- Design Basis of Immersed Tunnel
- Design report Immersed Tunnel
- Design report Innovative Tunnel Design
- Structural Drawings of baseline IMT and Innovative IMT
- Temporary works of Immersed Tunnel
- BIM/Revit Design

Rupel tunnel, Belgium

Project

To promote shipping traffic between Brussels and Antwerp the Brussels-Schelde channel is being prepared to allow passage of ships up to a Gross Register Tonnage of 10.000 (GRT). The channel will be prepared by deepening to a water depth of 9.50 m over at least 25 m width. TEC studied the impact of deepening of the channel on the structural integrity of the existing tunnel.

Construction of the Rupel tunnel started in 1972 and the tunnel opened for road traffic in 1982. The Rupel tunnel comprises a 6-lane motor road, about 1,650 m long with a closed tunnel length of 595 m. The tunnel contains two main tubes, each with a 3-lane roadway, a narrow central gallery and is made up of two submerged tunnels (under the river Rupel and under the channel) connected by a tunnel constructed in situ.

Based on the original design documents buoyancy, cross-sectional and longitudinal analyses were performed to analyse the impact of deepening of the channel on the structural integrity of the tunnel. The analyses were validated by comparing calculated deformations with recent settlement surveys. Also a design for the dredging and protection of the river bed above the tunnel was made.

The anticipated settlements would lead to additional rotations in already leaking segment joints. The cause of leakage was investigated, multiple proposals for repair where given and weighed to risk and costs. Eventually an integral plan for deepening of the channel in association with the repair of a leaking joint and monitoring of settlements during dredging was delivered.

TEC's scope of work

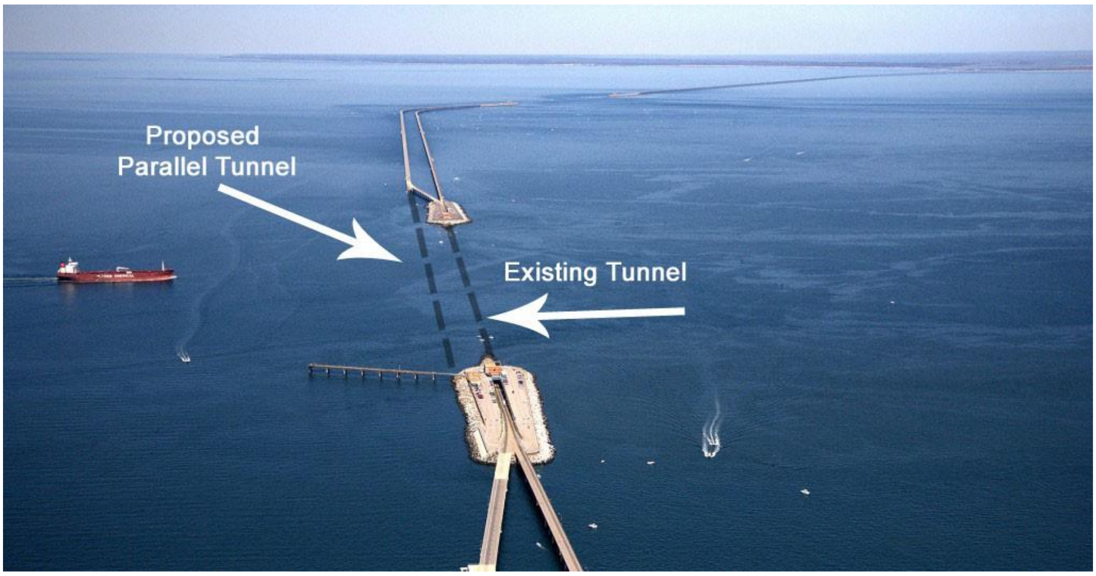
- Research characteristics of the fairway and the shipping traffic
- Checking of structural integrity of the tunnel due to deepening of the channel
- Design of tunnel protection
- Inspection of the tunnel
- Proposal for repair of a leaking segment joint
- Review of tunnel's dredging monitoring plan

Chesapeake Bay Bridge Tunnel - Parallel Thimble Shoal tunnel

Project description

Tunnel (CBBT) is a 30-km long 2-lane facility consisting of highways, bridges, tunnels (2 sections of 1.8km each) and artificial islands (connecting tunnel and bridge sections) connecting the Eastern Shore of Virginia with the Virginia mainland. The Bridge-Tunnel was opened to traffic in 1964, replacing the ferry service that had served the Eastern Shore for more than 30 years. The facility was expanded in the late 1990s to include parallel bridges (becoming 2x2 lane), which were opened to traffic in April 1999.

In 2015-2016 the expansion of the first of the two tunnels was tendered. The Parallel Thimble Shoal Tunnel Project will construct a new two-lane tunnel under Thimble Shoal Channel. When complete, the new tunnel will carry two lanes of traffic southbound and the existing tunnel will carry two lanes of traffic northbound.



Scope of work

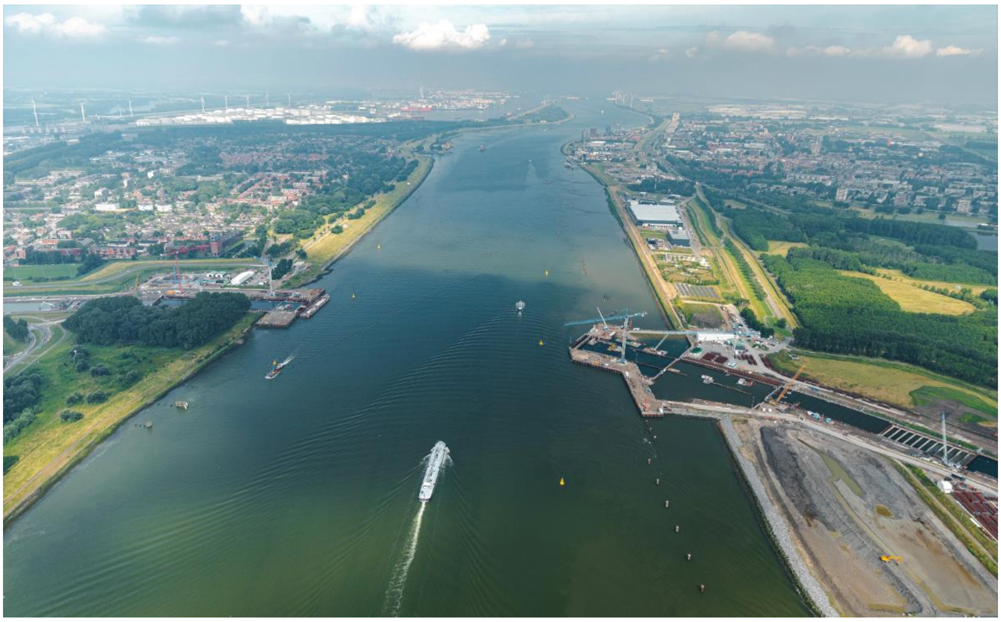
TEC was a member of a design JV led by Arup New York and covered the following scope of work:

- Design development of immersed tunnel option, parallel to the existing immersed tunnel including mitigating protective measures (for comparison to the bored tunnel option, which finally became the preferred and selected option)
- Review of Geotechnical FE analyses (Plaxis), carried out by the BTM design team to analyse the impact of the bored tunnel (construction) to the existing tunnel
- Assessment of the existing steel immersed tunnel regarding the impact due to the construction of the new parallel bored tunnel.
- Marine works design of the island protection and protective works on the tunnel
- Assessment of ship impact on the new tunnel and the protective works on top of the tunnel
- Design temporary jetty (construction purposes)
- Participation in (internal) design workshops and Clients' meetings

DBFM Blankenburg Link A24, the Netherlands

Project

The Blankenburg Link will connect motorway A20 near Vlaardingen (North bank) to the motorway A15 near Rozenburg (South bank) by means of the new motorway A24, accommodating 2x3 lanes. The new link contributes to a robust road motorway network in the Rotterdam Area and improves the connection between the Rotterdam Port and the economic heart of the Netherlands, the Randstad.
The connection of the new motorway A24 to the existing motorway A15 and A20 will be realized with several flyovers and underpasses. The new A24 will be integrated in its' environment and consists amongst others of a land tunnel (Holland tunnel) on the North bank to limit the environmental impact and an immersed tunnel (Maas Delta Tunnel), crossing the main access channel to the Rotterdam Port, het Scheur (Nieuwe Waterweg). The new motorway will be opened to traffic in 2024.



(photo RWS)

Scope of work

TEC is the main consultant to the BAAK DBFM Consortium for the tunnel related design services (civil and MEP) for:

- Holland tunnel, land tunnel with a length of approx. 1.35km, with a closed section of 510m to be constructed in an environmentally sensitive area.
- Maas Delta tunnel with a length of approx.1.7km including an immersed section of 385m, comprising of two elements with lengths of 185 and 205m

The services were provided for the (winning) tender design, preliminary design, final design, detailed design and site engineering. For the project a full integrated 3D BIM model was developed that was used for an integrated tender design and further detailed up to the preparation of construction documents (LOD350) for both civil and MEP works.
In addition, TEC held key positions in integrated design management, stakeholder management and technical committees.

Shanghai Outer Ring Tunnel, China

Project

The Outer Ring Tunnel under the Hangpu River has been built as immersed tunnel. The tunnel stretch has a length of 1.860km and includes cast in-situ tunnels on both riverbanks and 7 monolithic tunnel elements, approx. 108m each, with a total length of 736, immersed in place to form the river section. The project construction commenced in December 1999 and the tunnel link is in operation since June 2003.

The immersed tunnel is experiencing significant settlements at one end of the section (Pudong side), issues with rubber seals (GINA and Omega) at some of the immersion joints and water leakages at various locations.

Scope of work

The Chinese Design Institute STEDI has requested TEC to provide specialist and independent consultancy services to assess the observed issues, provide potential explanations and prepare repair and mitigation measures.

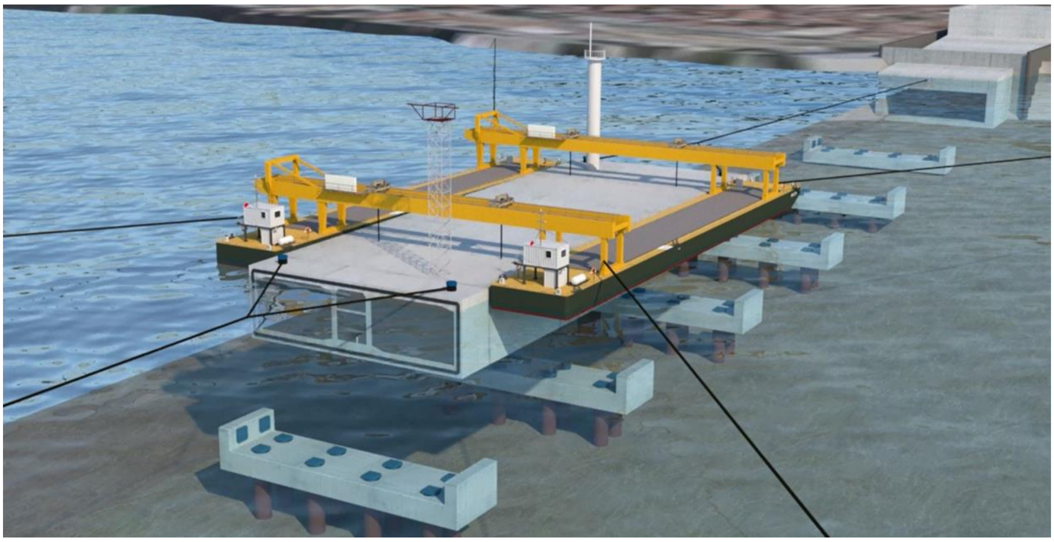
1. Analyse (including back-analyses) the tunnel settlement behaviour, especially in longitudinal direction at various stages (years) including the current stage. This includes the assessment of the bearing capacity and durability of the immersed section.
2. Develop potential future settlement scenarios and assess the bearing capacity and durability of the immersed section.
3. Develop retrofitting options that can be utilized when overloading of the structures can be expected:
   - Structural strengthening options
   - Ground improvement options
   - Unloading options
4. With regard to the issues of GINA gaskets at some joints, analyse the possibility of installing an additional water stop; assess the element joint repairment scheme proposed by STEDI and provide suggestions.

5. A general assessment of the observed leakages of immersed section including potential repair methods (crack treatment for different kind of cracks).
6. Provision of other suggestions for the overhaul of the immersed section of the Shanghai Outer Ring Tunnel (focus on minimizing disruption to the tunnel operation → maximize availability of the very busy tunnel).

Golden Horn Unkapanı Tube Tunnel

Project

The Istanbul Metropolitan Municipality (IBB) planned the Golden Horn Unkapanı Tube Tunnel in order to replace one of the congested bridge crossings of the Golden Horn. The tunnel cross section would accommodate two traffic tubes with 3 lanes each and a central gallery with a section for evacuation in the lower part and smoke extraction in the upper.



The geology in the Golden Horn is characterized by 30-40 m soft layers on top of weathered sandstone and siltstone. The riverbed is at 35 m below water level and considered deep. Due to the combination of steep slopes, dense population and the need to connect to the boulevards a tunnel below riverbed was not possible. A submerged tube bridge was therefore the most suitable option. For local shipping a navigation channel of 8.5 m deep and 300 m wide had to be accommodated.

Due to the vicinity of the North Anatolian Fault the design had to meet severe seismic design criteria. In order to reduce both internal forces and deformations in a reasonable manner, the tunnel was designed as a ‘limited flexible’ structure, meaning that connections would have sufficient flexibility to accommodate differential displacements, with restraints that are activated gradually.

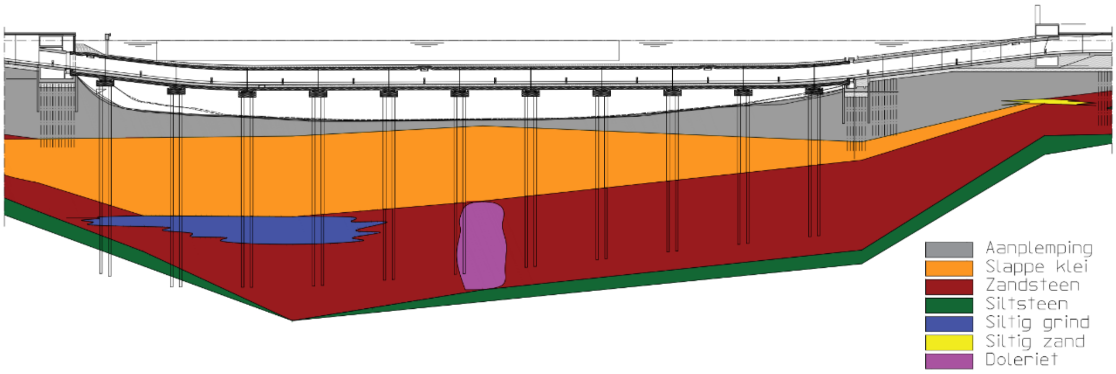


Figure 1: Longitudinal section of Reference Design with geology and navigation channel.

Based upon a reference design and tender requirements the Tender Design was developed which was dictated by the seismic circumstances requiring special joint detailing. For the longitudinal tunnel design, this resulted in a layout of one short permanent prestressed tunnel element at each end and connected to the land tunnel abutment and with longer tunnel elements in between. The immersion joints (joints between the tunnel elements) are prestressed after immersion. A special flexible joint was developed at both abutments allowing for displacement of +/- 0,5 meter.

The tunnel elements are supported by pile bents consisting of 2.5 m diameter steel piles with a socket into the rock and precast capping beams installed with suitable marine works equipment. The elements will be constructed on a different location under semi-floating conditions and after completion transported to the site in Istanbul over approximately 40 kilometres.

After the construction tender submission IBB selected the joint venture Yapı Merkezi-STFA-ASL Inşaat Group to build the tunnel, with TEC as design and engineering consultant. Because of changing political priorities, the project was put on hold shortly after the selection of the successful bidder.

Scope of work

TEC supported by local Turkish partner RHDHV-ELC was responsible for the tender designs for:

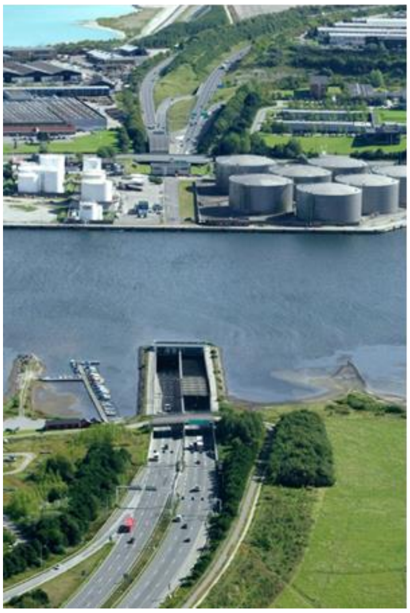
- the immersed tunnel including the foundation structures (civils),
- the tunnel installations (MEP),
- the temporary works for the construction, transportation, and immersion of the tunnel elements
- the interfaces at the abutments with the in-situ tunnel.

Special attention was given to the seismic design which was performed with use of the FEM program SAP-2000.

Limfjord tunnel, Aalborg Denmark

Project

The existing tunnel link between Aalborg and Nørresundby is a highway tunnel crossing below Limfjorden. The immersed tunnel is a monolithic reinforced concrete structure that was constructed during the late sixties. From the very beginning the tunnel is suffering leakages especially in the middle section of the tunnel. Several (major) repair campaigns have been undertaken but did not provide the ultimate solution of stopping the leakages. Annual injection campaigns remain needed to manage the leakage issue. From a durability point of view this has becoming more and more a concern for the Owner.
Additionally, continued settlements are observed since 1969, in the northern section of the immersed tunnel reaching as much as 130 mm, which can be considered as substantial. This has given another reason for concern for the Danish Road Directorate.
To clarify the remaining lifetime of the tunnel, the Danish Road Directorate has established a geotechnical and structural expert group, to further analyse both the above issues.



The geotechnical expert group acted in the period of May 2017 to April 2018 under the mandate of identifying the reasons for the observed settlements and predicting additional settlements until 2070. The structural expert group worked in the period of May 2018 to June 2019 using the results of the geotechnical working group:
Extensive condition assessment, from a structural and material degradation perspective
Describe a long-term maintenance plan and outline one or more repair project(s) including impact for the availability of the tunnel.

The structural working group consisted of experts in the field of immersed tunnelling, structural en geotechnical engineering and concrete repair strategies. The working group carried out detailed condition assessments and defined scope

packages for further detailing by assigned project teams. The following studies were undertaken:

- Structural condition assessment in both transverse and longitudinal direction and verification in accordance with the Eurocodes or more state-of-the art design codes. This included the definition of, the assessment of and verification against future settlement scenarios subjected to the tunnel structure.
- Comprehensive physical condition assessment of the tunnel structure (destructive and non-destructive testing material, chemical content, chloride and water content, HCP measurements). The working defined the testing scope and interpreted the test results.
- Assessment of the tunnel joints.
- Development of Basic Maintenance and Repair Strategy; basically a "business as usual" -strategy supplemented by additional activities recommended by the Expert Group.
- Retrofitting Projects; the remedial actions include geotechnical and structural retrofitting projects.
- Development of a set of criteria to monitor the tunnel behaviour in the next 50 years with threshold levels for the implementation of retrofitting projects.

The overall conclusion of the extensive condition assessment by the working group is that it is considered very unlikely that the tunnel will exceed safety requirements in the next 50 years. The Basic Maintenance and Repair Strategy combined with a monitoring plan and back-up retrofitting plans to be implemented in the unlikely case of sudden decrease of the tunnel condition, was considered a viable Operation and Maintenance strategy.

Scope of work

TEC participated in the structural working group and undertook tasks such as structural assessment in transverse direction, the development of an advanced nonlinear FE model and verification against state-of-the-art design codes and in-depth reviews of documents prepared under the supervision of the expert group.

BORED TUNNELS

General

TEC, a permanent joint venture between Royal HaskoningDHV and Witteveen+Bos, has been involved in the following bored tunnel projects:

- Westerschelde tunnel, The Netherlands
- Sophia railway tunnel, The Netherlands
- Tunnel Pannerdensch Canal, The Netherlands
- Lisbon Blue-line metro tunnel, Portugal
- Groene Hart tunnel, The Netherlands
- Genoa Harbour Crossing, Italy
- Hubertus tunnel, The Hague, The Netherlands
- Bored tunnel North South metro line, Amsterdam, The Netherlands
- Sluiskil tunnel Netherlands
- 2nd Heinenoord tunnel
- Metro Dublin North – Ireland
- Fehmarnbelt tunnel, Denmark-Germany, Comparative Study
- Shenzhen-Zhongshan Link, Guangdong Province China
- New Centennial Water Source Project, Philippines
- Replacement of the Existing Water Siphons Brooklyn - Staten Island
- Tuen Mun-Chep Lap Kok Link, Hong Kong
- Shantou SuAi crossing, Seismic analysis, China
- Bored tunnel Oosterweel, Antwerp
- Fast Track 3A Cooling Water Intake System, Malaysia
- Blauwe Ader: Hasseltstraat - Midden Brabantweg

Westerschelde tunnel, The Netherlands

Project

The Westerschelde tunnel is a bored tunnel in soft soil and accommodates a dual carriage motorway in two tubes. The bored tunnels have an inner diameter of 10.1 metres, are approximately 6.5 km long and reach to a maximum depth of 60 metres below sea-level. The total length of the crossing is about 7.0 km long. Transportation of hazardous goods is acceptable according to the category I tunnel classification. For safety reasons both tubes are connected with cross connections every 250 metres.

Figure: Start shaft

TEC's scope of work

Scope of work contains reviewing the contractors detailed design of the bored tunnel, cross connections and access ramps; reviewing work method statements, quality plans and construction planning; monitoring of investigations for the design (fire-tests, freezing test for cross connections); advice with respect to local damage of lining during construction.

Sophia railway tunnel, The Netherlands

Project

The Betuweroute freight railway line runs from the port of Rotterdam to the German border. One of its main components is the Sophia railway tunnel, taking its name from the Sophia polder, which is located approximately halfway along the tunnel. The tunnel is 8 km long, making it the Betuweroute's largest structure.

The main part of the structure consists of the bored tunnel tubes with a length of 4.240 m each. At both sides of the bored section, cut-and-cover and open tunnel sections complete the tunnel.

A hydro-shield was chosen for the boring process since the ground in this part of the Netherlands is very soft. For this project the continuous boring technique was tested for the first time. In this special boring process the rings of the tunnel are being constructed while boring simultaneously. By using this technique, approximately 40 m of tunnel can be constructed in a day.

The tunnel has an exterior diameter of 9.45 m. Each ring has an average length of 1.5 m and consists of 7 concrete segments of approximately the same size. Each segment has a thickness of 0.4 m and weighs 6.2 tonnes.

Figure: TBM

Figure: tunnel lining

TEC's scope of work

TEC has been involved through its partner Royal Haskoning in:

- Tender Documents / Contracts
- Design
- Document review
- Site supervision
- Study
- Technical assistance

Tunnel Pannerdensch Canal, The Netherlands

Project

The Tunnel Pannerdensch Canal is part of the 150 km cargo railway between Europoort (Rotterdam) and Germany. The bored section is 1800 m long and consists of 2 tubes with 8,65 m internal diameter.
The tunnel is situated in varying soil conditions mainly consisting of sand and local clay layers. The eastern part is located in a former sandpit, which has partly been filled with a stable sand body. In this way the boring process could be continued through the sand body up to the eastern margin of the sandpit.
In a section where the overburden was not sufficient with regard to stability of the tunnel, an extra layer of magnetite ore has been applied, to improve stability.
Both tubes are interconnected by means of two cross passages. One has been constructed starting from a vertical concrete shaft between the tubes that had been brought down before the start of tunnel boring activities. The shaft contains the pumps for leak water discharge of the tunnel. The other cross passage has been built directly from one tube to the other one. The cross passages have been built by means of soil freezing technique.
The tubes of the tunnel consist of rings composed of curved pre-cast segments in reinforced concrete. The detailed engineering has been performed in narrow cooperation with manufacturers of the segments and the reinforcement cages. Besides the technical requirements of durability, structural safety and water tightness, the requirements of transport and construction have been considered in the design.

Figure: TBM shield

Figure: Cross passage

TEC's scope of work

TEC has performed, through its partner Royal Haskoning the following activities:

- The contractor design of the bored section of the tunnel.
- Calculation and detailed engineering of the tunnel segments.
- Check of underlying geotechnical calculations.

- Design and calculation of the vertical shaft between the tunnel tubes.
- Design and calculation of temporary auxiliary structures for the construction of the cross passages.
- Design and calculation of the sand body in the former sandpit.

Lisbon Blue-line metro tunnel, Portugal

Project

In the late 1990’s, it was decided that “Blue-line” of the Lisbon metro should be extended in southern direction towards and later parallel to the river Rio Tejo (Tagus) towards the Santa Apolónia railway station. The tunnel was made using a 9.5 m diameter TBM. Along the line extension, also a new station would be realised. During the construction works, a partial collapse of the tunnels occurred and both tunnel tubes were flooded. Several damage control measures were taken.

Following extensive inspections and damage assessments, it was determined that following dewatering of the tunnels, remedial works could be implemented to restore the functionality of the tunnel. The remedial works were required over a length of some 350 m.

The remedial works mainly consisted of repair works on the existing lining and the addition of a second lining inside the tunnel. The second, inner, lining has been designed with the help of state of the art Finite Element models.

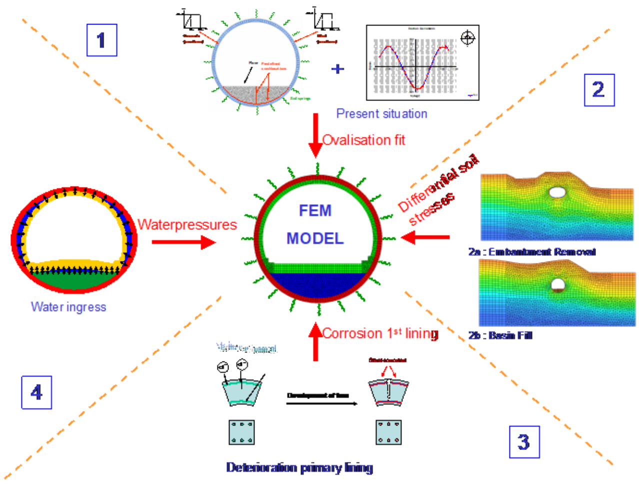


Figure: Calculation strategy Metro Lisbon

Figure: inner lining formwork

TEC’s scope of work

Following the inspection after the event, TEC advised the Client on the structural capacity of the tunnel. Furthermore a preliminary, basic and detailed design was prepared for the remedial works that included consideration of the seismic aspects. TEC also provided for the technical requirements for the secondary lining which had to be implemented inside the (existing) tunnel and some secondary works.

TEC provided for the monitoring and supervision during the execution of the remedial works.

Groene Hart tunnel, The Netherlands

Project

The “Boortunnel Groene Hart” is part of the HSL-Zuid high speed railway line, and consists of a bored tunnel and access ramps. The total length of the tunnel including access ramps is approximately 8.6 km. The bored tunnel consists of one tube with an inner diameter of 13.3 m and is 7.2 km long.

For safety reasons three emergency shafts are implemented in the alignment and a central wall separates the two tracks. The emergency shafts are constructed as circular construction pits with an inner diameter of 30.2 m and a depth of 40 m. These pits are made with diaphragm walls and an underwater concrete slab. The final concrete structure is constructed inside this pit.

The access ramps consist of an open and closed part as well as a technical building and entry or exit shaft for the TBM. The deepest part of the ramps, with a depth between 15 and 23 m, are made inside construction pits consisting of diaphragm walls and an underwater concrete slab. This slab is anchored by Barrettes, elements of diaphragm wall panels. The concrete structure is made inside this pit and consists of concrete slab/roof and counter walls. The open ramps are made as common structures inside sheet pile-wall upon an underwater concrete slab.

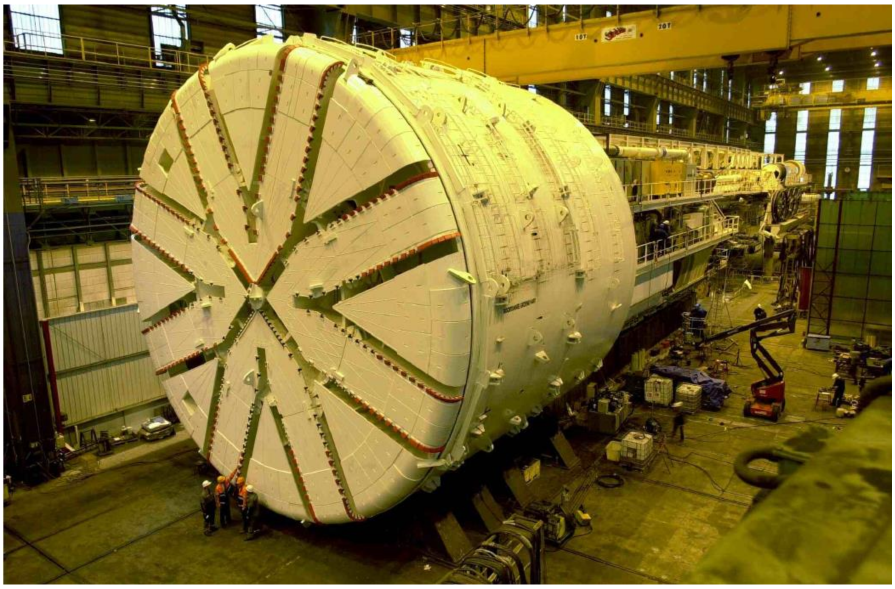


Figure: The 14.5m diameter TBM for the Groene Hart tunnel

TEC’s scope of work

TEC has been involved through its partner DHV as client’s consultant in the preliminary design, design, commissioning, monitoring and supervision of the “Boortunnel Groene Hart”. In addition to this TEC has carried out the detailed design of the start- and exit shaft, approaches and emergency shafts for the contractor Bouygues.

Genoa Harbour Crossing, Italy

Project

The Genoa Harbour Crossing is a project concerning an approximately 4 km long road connection through the port of Genoa with 4 junctions to the city. The harbour crossing is designed as a bored or immersed tunnel and is suitable for 2 times 3 lanes road traffic.

Figure: Tunnel alignment Genoa

TEC's scope of work

In the study several solutions are considered for a tunnel (immersed and bored), including ramps, viaducts and junctions to the city road network. In the study the different alignments and designs are compared. In co-operation with the Client, a decision was made for the solutions to be taken into account in the preliminary design. During the preliminary design both a bored (diameter 15 meter) and immersed tunnel are considered. For both options a preliminary design was made. Services have been provided in cooperation with HPR, D'Appolonia and Technital.

Hubertus tunnel, The Hague, The Netherlands

Project

The Noordelijke Randweg The Hague is a local connection in preparation from Leidschendam with the Hubertus fly-over and connects the roads to the centre of The Hague and Scheveningen. The part that connects the Hubertus fly-over, which is situated in the municipality of The Hague, will mostly be situated below surface. The proposed route runs parallel to the Oude Waalsdorperweg, is situated on the grounds of the Frederik and Alexander barracks and crosses the Hubertusduin, which is a beautiful dune area.
The total route has a length of ± 2000 m, the underground part has, inclusive the slip roads, a length of 1700 m and consists of a twin bored tunnel with an outer diameter of 10.2 m.

Figure: Hubertus tunnel

TEC's scope of work

Feasibility study

In this phase the technical and economical proposition of the various possibilities of execution for the tunnel is investigated. Besides bored alternatives the traditional methods have also been investigated.

Reference design

For the Engineering & Construct contract, a reference design was made for two options: twin tube solution with cross connections and a single tube solution. For the bored tunnel preliminary design calculations were made with DIANA. For the contract documents TEC has contributed to the Terms of References, geotechnical baseline reports and other necessary input for the Client.

Final design

For the Engineering & Construct contract TEC has made the final design calculations for the tunnel lining. Also the coordination with the contractor and review of contractor documents belonging to the bored tunnel part was done by TEC.

Monitoring and supervision

During construction TEC has taken care of monitoring and supervision of the bored tunnel section.

Bored tunnel North South metro line, Amsterdam, The Netherlands

Project

The following project characteristics apply: double tube bored tunnels passing through 3 deep stations and 6 cross passages and emergency exits.

From the north end of the Damrak all the way down to Scheldeplein, the route of the Noord/Zuidlijn will be excavated by two tunnel-boring machines. The machines will bore both tunnels with a time difference of about three months between the first and the second.

In the route chosen for the Noord/Zuidlijn, the tunnel-boring machines can follow the existing street pattern. That means that almost no buildings need to be demolished in the process.

The tunnel shafts will have a diameter of about 7 metres. They will be 3.8 km long – or 3.2 km if the length of the platforms in the stations that the boring machines will pass through is left out.

Each tunnel-boring machine has a diameter of 7 metres and is approximately 60 metres long. Both machines will be assembled in the launching shaft – a construction pit some 20 metres deep in the water of the Damrak.

Just past the Scheldestraat, the bored tunnel will end in the reception shaft – a construction pit about 15 metres deep, where the boring machine will be dismantled and removed.

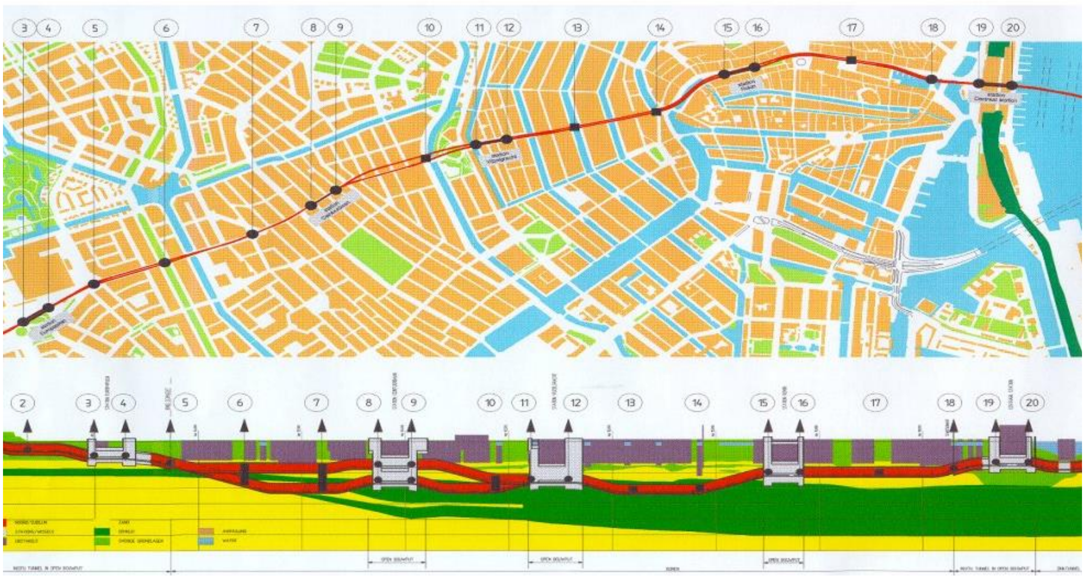


Figure: Plan and alignment of bored tunnel section

TEC Tunnel Engineering Consultants

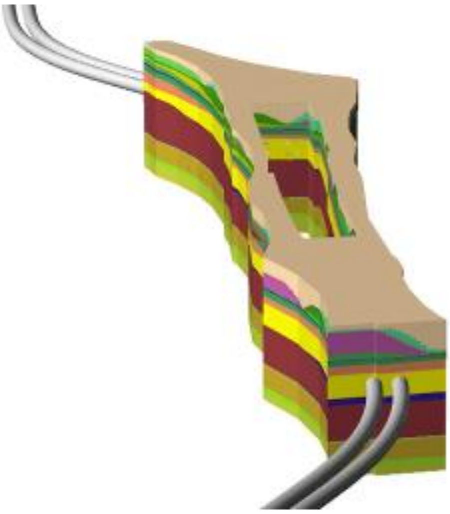


Figure 3D geotechnical model

Figure: the TBM for the Amsterdam NZL

TEC's scope of work

Since 1994 the TEC partners Royal HaskoningDHV and Witteveen+Bos are involved as clients consultants in the project. The scope of work included amongst others preliminary design, design, commissioning, monitoring tender preparation, detailed design and supervision of the total project.

Sluiskil tunnel Netherlands

Project

The Sluiskiltunnel will be built alongside the present bridge over the Channel from Gent to Terneuzen. It is situated south from the Westerschelde tunnel and will provide a better connection between the harbours of Antwerp and Rotterdam. As this Channel is sailed by many Ocean Bulk Carriers the bridge is opened for 5 hours per day now. A new bored tunnel will provide a permanent available connection for the increasing (cargo) traffic. The Sluiskiltunnel is a 1600 m twin bored tunnel with a diameter of app. 11 m. and on both sides of the Channel ramps of about 300 m. The tunnel is built in soft subsoil in a polder area. Ground conditions vary from salty sand to Boomse clay. A slurry TBM will be used in order to reduce risks during the passage of the Channel dikes and 3 railway lines. The works will be conducted under a Design & Construct constellation.

TEC's scope of work

- Preliminary Design of ramps, bored tunnels and technical installations
- Definition of Employers Requirements
- Cost estimates
- Competitive dialogue negotiations with contractors consortia
- Checking detailed design of contractor for ramps, bored tunnels and technical installations
- Commissioning of tunnel segments and TBM
- Construction supervision

2nd Heinenoord tunnel

The 2nd Heinenoord tunnel is the first bored tunnel in the Netherlands and crosses the Oude Maas waterway near the city of Barendrecht in the Netherlands.

In the initial (1st) Heinenoordtunnel, which is an immersed tunnel, there were two lanes for slow traffic and cyclists. These lanes had to make way for fast traffic. Therefore, a new tunnel had to be realised and it was decided to make this a TBM tunnel with two tubes, to be bored next to the existing tunnel. One tube was intended specifically for farming traffic, the other for cyclists.

This tunnel is the first TBM tunnel in the Netherlands and was set-up with a distinct research character, i.e. like a Joint Industry Project where the government, contractors, consultants and universities joint forces to investigate, design, monitor, and realise the tunnel.

The project was initiated in 1994 and completed in 1999. The tunnel has a total length of 1064m while the TBM part measures some 614 m. Both bores have a diameter of 8.3 m and have a wall thickness of 0.35 m.

Picture: RWS

TEC’s scope of work

As previously stated, the research in connection with the preparation of the 2nd Heinenoord tunnel project was a combined effort between the various universities, design and consultancy companies and other research institutes. These were all combined into the “Centrum Ondergronds Bouwen” (Centre for building below surface).

The research and development of COB is conducted within the framework of a comprehensive implementation programme. This programme is initially divided into four themes, i.e.

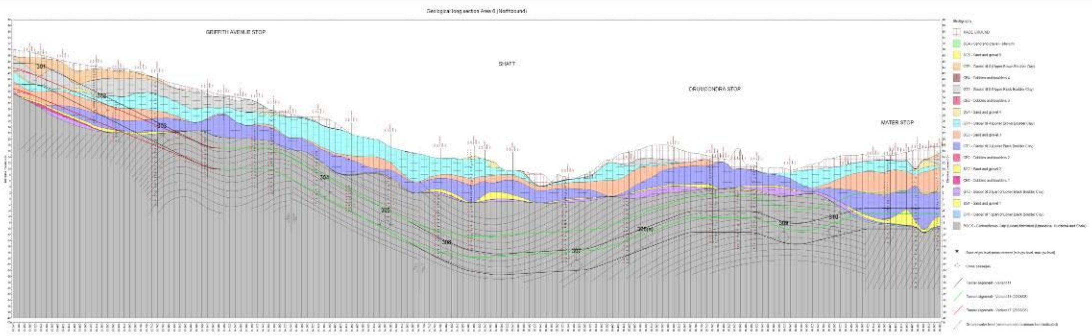
- “Tunnelling in soft soil,”
- “Exploring, predicting and monitoring,”
- “Economical tunnel construction,” and
- “Constructing, administering and maintaining.”

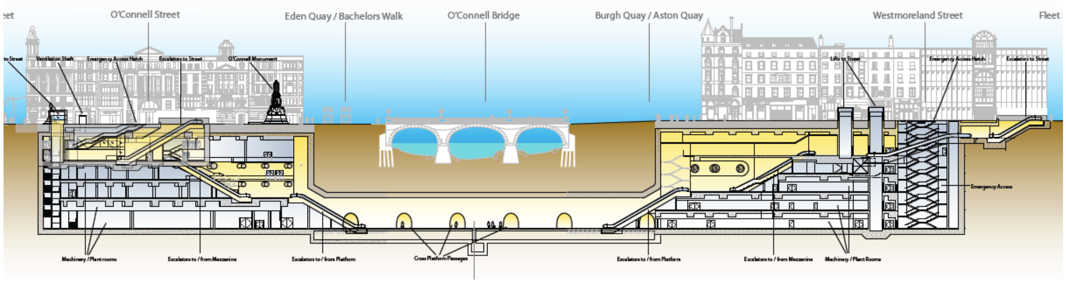
The themes are fleshed out by carrying out research and development projects. An important project within the first theme is the “Pilot Project Bore Tunnels” (COB Commission K100). TEC as well as its mother companies Royal HaskoningDHV and Witteveen+Bos have contributed to the various commissions covering the large variety of TBM development related subjects.

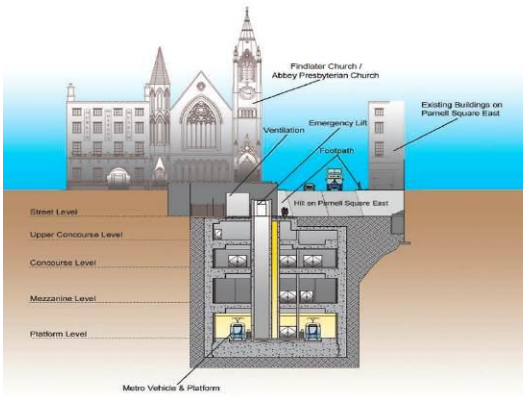
Metro Dublin North – Ireland

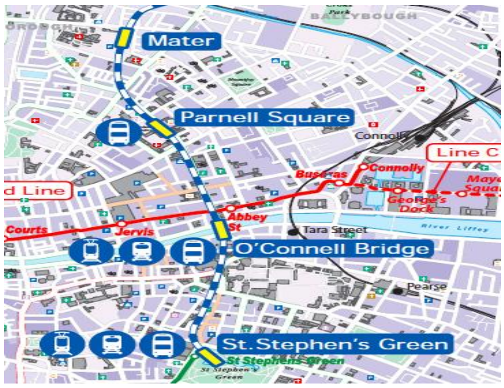
Project

This project was a tender design for DBMFO contract for an 18 km long metro line from Dublin Airport to the heart of Dublin City Centre. 50% of the total length was planned to be underground in two separately bored tunnels. Next to the twin bored (app. 7 m OD) tunnels 7 deep subsurface stations were planned to be executed. The geology of Dublin consists of glacial till deposits overlying Carboniferous bedrock consisting mainly of limestone and shale. The Carboniferous rocks are heavily folded, faulted and jointed. The bedrock level is also strongly undulating. The tunnels and stations were to be constructed largely within the Carboniferous bedrock.









TEC's scope of work

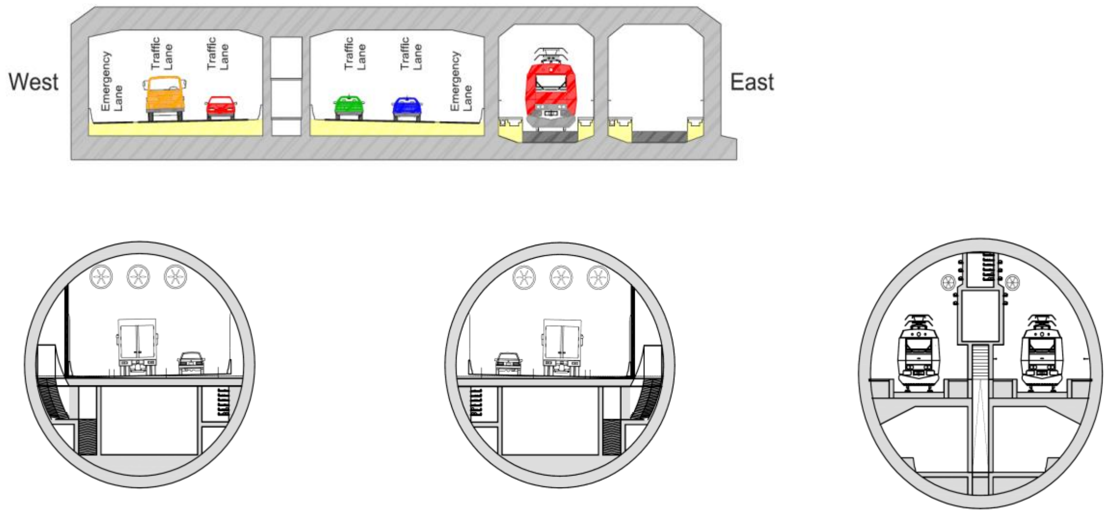
- The construction of geological long sections along the entire alignment on the basis of about 400 soil and rock borings.

- Compilation of a geotechnical interpretative report.
- Preliminary design of TBM alignment and tunnel cross section including preliminary lining design. Review of contractor design.
- Alternative design of additional 1,5 km of bored tunnels.
- Advise on TBM type in geological conditions varying from silt to coarse sand to Carboniferous rock.
- Geotechnical and Structural design of 5 deep subsurface stations (St. Stephens Green, Parnell Square, Griffith Avenue, Matter, Drumcondra, Airport) within the inner city of Dublin.
- Settlement Risk Assessment studies along the whole underground route of the bored tunnel and along the deep stations.
- Advise on the implementation of mitigation measures such as permeation grouting, jet-grouting and compensation grouting.

Fehmarnbelt tunnel, Denmark-Germany, Comparative Study

Project

The Fehmarnbelt Fixed Link will be the third major fixed link in the Danish Road Network and will serve as a direct road and rail connection between Scandinavia and continental Europe. The 19 km long tunnel will accommodate a 2x2 lane motorway with hard shoulders, an emergency annex utility tube and a double track railway. This will make it one of the largest fixed links on this planet. The costs for the realization of the tunnel have been estimated at EUR 5.1 billion. The costs for modification of the infrastructure at the Danish and German side of the link have been estimated at EUR 1.5 billion, which make the total cost EUR 6.6 billion. The preparation and design works for this project are expected to take another three years. The fixed link is intended to become operational at the end of 2020.



Illustrative figure from comparative studies

TEC's scope of work

TEC plays a key role in the JV RAT design team to develop the Integral Immersed Tunnel option as the preferred option for implementation. The Tunnel Design services comprise the following stages:

1. Conceptual Design (a detailed and comprehensive comparison between bored concept and immersed tunnel had been carried out)
2. Plan Approval Design (including an update of the comparative study immersed – bored tunnel)
3. Illustrative Design
4. Enquiry Documents and tender period
5. Tender Evaluation
6. Review of Basic and Detailed Design (in case of D&C contract), Detailed Design (in case of DBB contract)
7. Monitoring and Supervision of construction works

Shenzhen-Zhongshan Link, Guangdong Province China

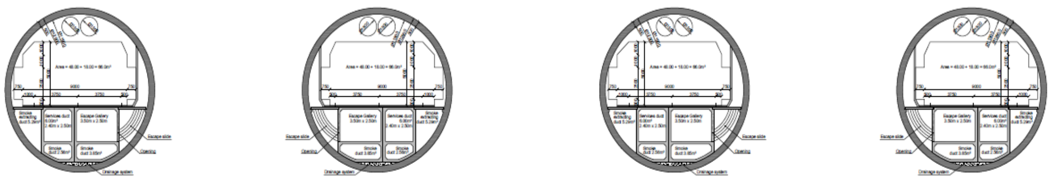
Project

The Shenzhen-Zhongshan link is located in the core area of the middle stream of Pearl River, which is about 30 km to Hu-Men Bridge in the north and about 40 km to the Hong Kong Zhuhai Macau Bridge (HZMB) in the south, and connects the Shenzhen Economical Special Zone with Zhongshan and Jiang-Men. The link is about 50 km of which over 20 km is offshore.

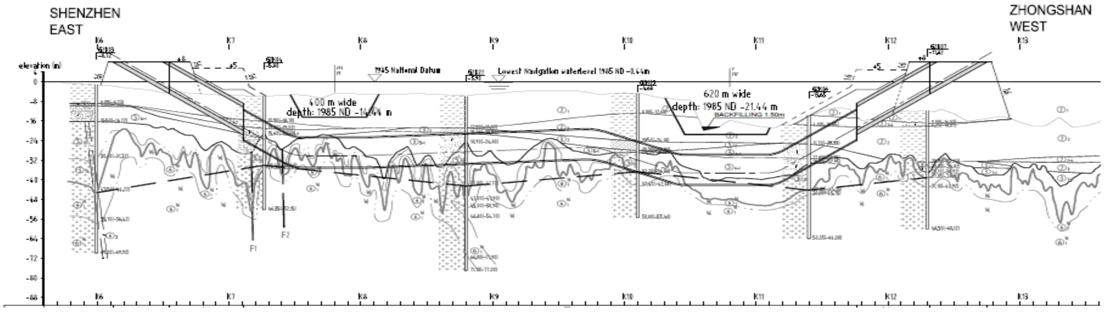
The Shenzhen-Zhongshan link project is one of the key and important infrastructure project in planning outline of development of Pearl River Delta.

For the offshore section studies have been performed for four alignments, considering bridge and tunnel options, the length of the tunnels in the various alignments ranges in between 6 km and 15 km. In order to accommodate the traffic volumes to be expected in the future a two way eight lane tunnel (four lanes in each direction) is likely to be required. To underpass the main navigation channels the deepest level of the tunnel is about 35 to 40 m.

The geotechnical conditions are varying from soft clay layers, sand, gravel to weathered and hard rock.



TBM cross section for all alignments



TBM Solution - Alignment

TEC's scope of work

TEC has carried out the entire and independent parallel concept design for different alignments of Shenzhong Link (two bridge-tunnel combined concepts and two full tunnel concepts), completed different alternative concepts for super long, deep and wide tunnel concepts for this link, including ventilation & safety design, cross section design and longitudinal profile design of TBM tunnel concepts.

Meanwhile, TEC also accomplished the construction methodology comparison and evaluation for TBM tunnel including risks and costs.

Regarding these aspects TEC also made comprehensive comparisons between bored tunnel concept and immersed tunnel concept and mined tunnel concept and provided the basis for client to make decisions.

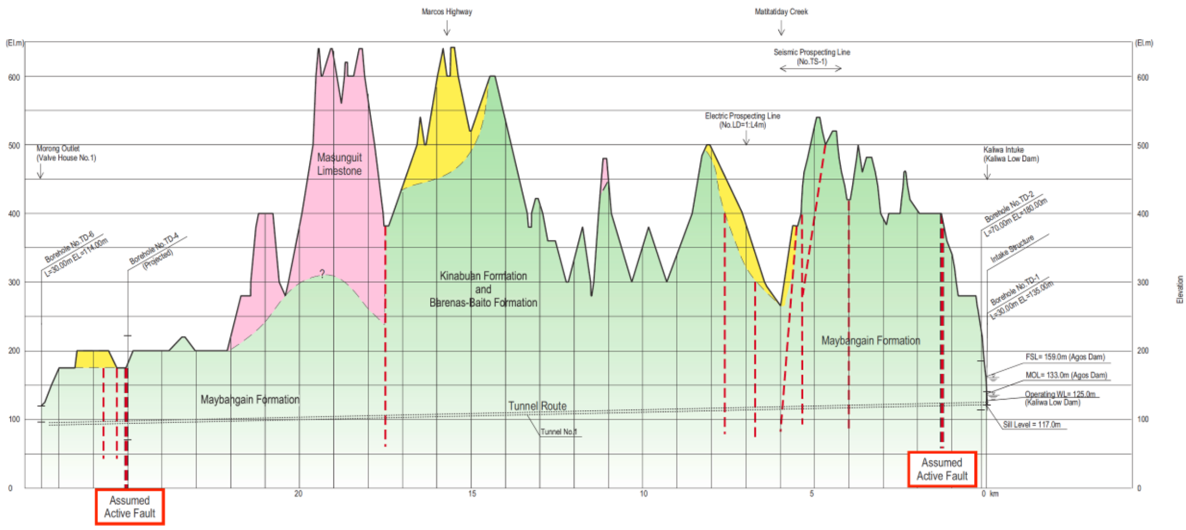
New Centennial Water Source Project, Philippines

Project

In the Philippines new hydropower plants are under investigation, like in many other upcoming countries in Asia and Africa. The New Centennial Water Source Project is a hydropower project in the mountains near Manilla, the capital of the Philippines. The project consists of one or two dams, a headrace tunnel of approximately 27 km and a powerhouse.

TEC's scope of work

The client needed a specialized consultant for the study regarding the project's headrace tunnels. For the feasibility study of the headrace tunnels and the preparation of the tender documents regarding this part of the project TEC has been assigned. Our task includes the assessment of the technical feasibility of the tunnels, including the selection of excavation method (TBM or Drill&Blast) and type of TBM. TEC also produced the draft project planning and an estimation of the construction costs. As part of the agreement, TEC will also produce the tender documents regarding the headrace tunnels.



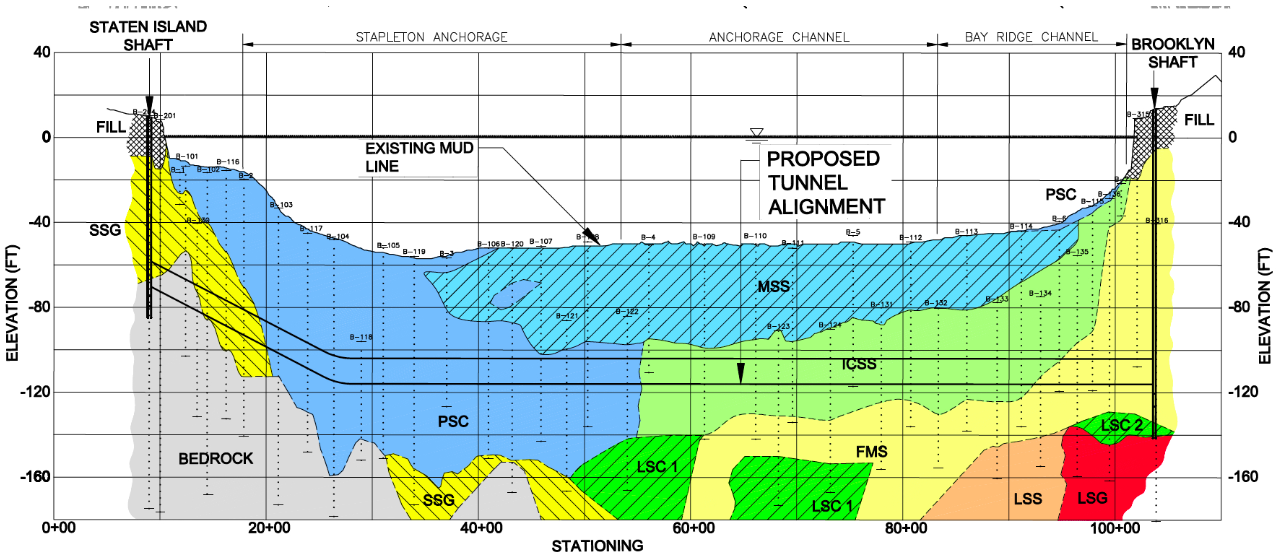
Replacement of the Existing Water Siphons Brooklyn - Staten Island

Project

On October 29, 2012 New York was affected by Storm Sandy. Sandy caused winds, rains, and an extraordinarily high tide level. The consequences of the storm include severe damages and more than 70 deaths. “The Replacement of the Existing Water Siphons between Brooklyn and Staten Island” project was also impacted by Storm Sandy. The storm flooded the project’s tunnel and severely damaged the TBM.

TEC’s scope of work

The project’s contractor, a Joint Venture consisting of Tully Construction and OHL, have asked TEC to consult on technical and legal matters regarding the restart of the project and the residual risks related to this restart. Furthermore TEC advises the JV on issues related to the Project’s insurances.



Tuen Mun-Chek Lap Kok Link, Hong Kong

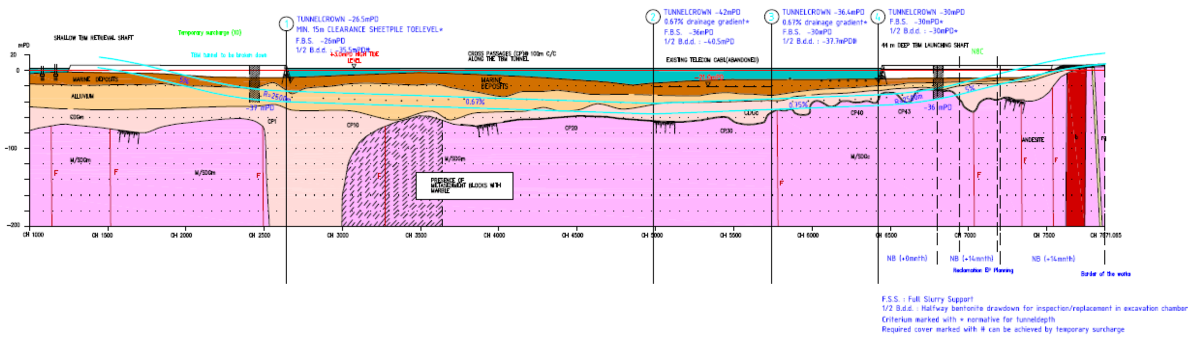
Project

The project comprises the tender design of a 15 m diameter approximately 6 km twin bored sub sea tunnel between Chek Lap Kok Airport on Lantau Island, Hong kong and the City of Tuen Mun on China Mainland. The Tuen Mun – Chek Lap Kok Link (TM-CLKL) sub-sea tunnel will be the longest and largest tunnel ever built in Hong Kong, posing unprecedented challenges. The use of large-diameter TBMs, operating under high water pressures, calls for a robust design, the most experienced personnel and fit-for-purpose equipment. The tunnel starts and ends at artificial islands yet to be constructed and is connected by cross passages every 100 m. The tunnel is both positioned in hard rock and soft soil and passes an array of subsea cables.

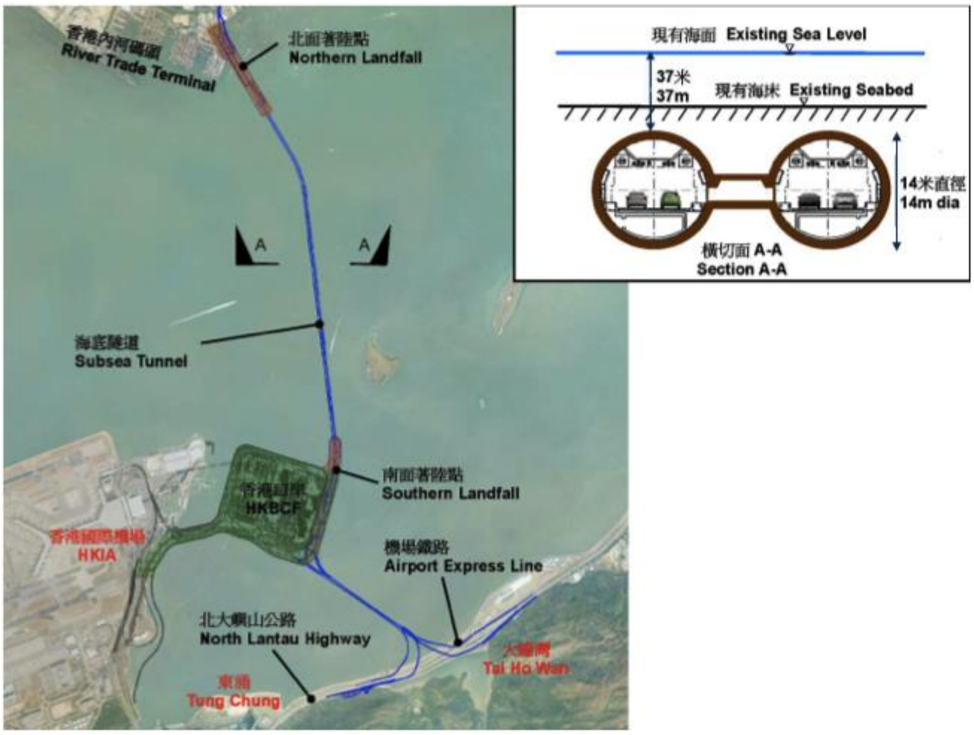
TEC's scope of work

A JV consisting of OHL (Spain)/Samung (S. Korea)/Chunwo (Hong Kong) have instigated a design team consisting of Meinhardt (Hong Kong) and TEC to provide a tender design for the TM-CLKL project. The services of Meinhardt-TEC JV consisted of;

- Optimization of tunnel cross section based on local requirements
- Determination of optimal tunnel alignment
- Structural calculations and tender design segmental tunnel lining
- Structural calculations and tender design cross passages
- Optimization and design of start and entry shaft
- Geotechnical risk assessment
- Face stability calculations
- Risk analysis
- Settlement risk assessment and monitoring plan of subsea cables
- Risk analysis and consulting regarding mechanized tunneling concept
- Durability assessment concrete structures
- Cost estimates, Value Engineering



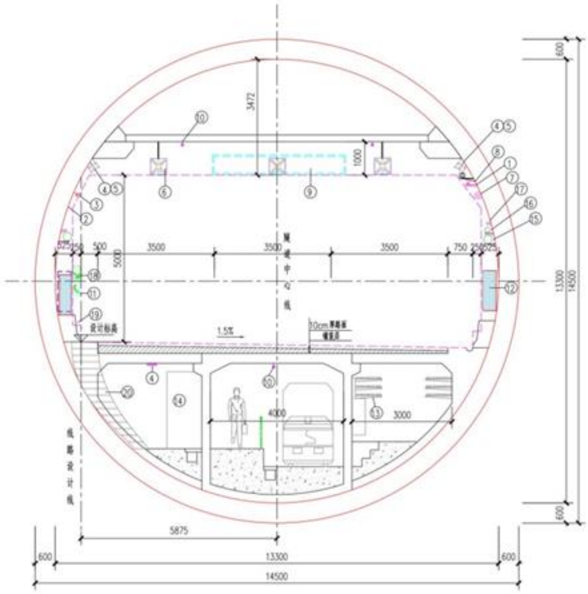
Longitudinal profile



Plan view and cross section

Shantou SuAi crossing, Seismic analysis, China

Project



The Shantou city is located in the eastern part of the Guangdong province in China, 300 kilometres east of Hong Kong. The Shantou SuAi crossing consists out of two identical TBM made tunnels with a length of 3,500 km crossing the SuAi river. The crossing will connect Longhy district at the northern bank and Haojinag district at the southern bank. Both tubes have an outer diameter of 14.50 m and accommodate 3 traffic lanes.

The responsible design institute has performed the necessary analyses, but since the tunnels are located in an area with high seismic intensity an independent analysis by an international consultant was considered. For this, China Railway Tunnel Design Institute (CRTDI) has awarded TEC to execute an independent seismic analysis.

TEC’s scope of work

From CRTDI seismic signals, recorded during previous earthquakes, were received. With SHAKE2000 the response of the soil to those earthquake signals was calculated from which the soil displacements during an earthquake where extracted. Those displacements where required to analyse the behaviour of the tunnel in cross-sectional direction and in longitudinal direction. For both directions a separate calculation model was developed.

For the cross-sectional analyses the displacements from the SHAKE2000 model were imposed on 2 adjacent tunnel rings modelled in 3D with DIANA. With the model the rotations in the segment joints, forces in the concrete and differential displacements between two rings were analysed.

For the longitudinal analyses the complete 3,500 km long tube was modelled with beam elements on which a propagating seismic wave was imposed. With this model the most critical sections along the alignment where identified. By installing the seismic joints on the right locations the joint openings between adjacent rings are limited to also guarantee water tightness in longitudinal direction.

With the performed analyses TEC advised China Railway Tunnel Design Institute on the location of seismic joints and the expected forces and gaps in the tunnel during seismic events. Results of the analyses were discussed with Guangzhou University and Southwest University. TEC also performed a review of the detailed design drawings of the seismic joints.

Bored tunnel Oosterweel, Antwerp

Project

For the expansion and relocation of the existing ring around Antwerp in total 4 bored tunnels for cables and pipelines are constructed to make possible the relocation of the existing highway to below ground level. The bored tunnels have the following specifications:

Location	Groenendaallaan	IJzerlaan	Schijnpoort
Type	single	single	double
Length	175 m	260 m	220 m
Diameter start shaft	15 m	15 m	25 m
Diameter end shaft	10 m	10 m	20 m
Outer diameter tunnel	4,1 m	4,1 m	4,1 m
Top point tunnel	20m below ground level	25m below ground level	25m below ground level
Bottom point shaft	25m below ground level	30m below ground level	30m below ground level

TEC's scope of work

TEC parent company Witteveen+Bos is responsible for Civil and Structural works:

- Preliminary design and final design
- Structural calculations and drawings
- Geotechnical calculations
- Tender documents
- Cost estimates
- Advisory and back office upon construction

Fast Track 3A Cooling Water Intake System, Malaysia

Project

A new 1 x 1000 MW coal fired power plant is to be built at Manjung site, Perak, Malaysia. This site is located on a man-made island next to an existing facility. The plant will utilize a once-through sea water circulating water system. The sea water intake is to be located approximately 1.8km offshore of the Island.

DAELIM has been awarded the construction of the new power plant. As part of the Scope of Works, DAELIM invited tenderers on a D&C basis for the offshore part of the cooling water system. The cooling water system consists of a combined intake velocity cap and offshore shaft, a 2.5km long, 5.8m diameter bored tunnel and an onshore shaft. The tunnel is to be constructed using EPB shield tunnelling. Also, the design of an offshore navigation marker is required. Afcons Infrastructure Limited approached TEC to act as their preferred designer for the Tender submission and to provide design services for the complete offshore system.

TEC's deliverables, whilst meeting the design requirements, enabled Afcons to submit a competitive price for the Tender package. TEC's design processes considered the preferred construction methods of and installation equipment available within Afcons to allow for a cost-effective approach to the design and ultimately construction costs. Alternatives were considered for comparison purposes and to meet design and contractor requirements.

TEC's scope of work

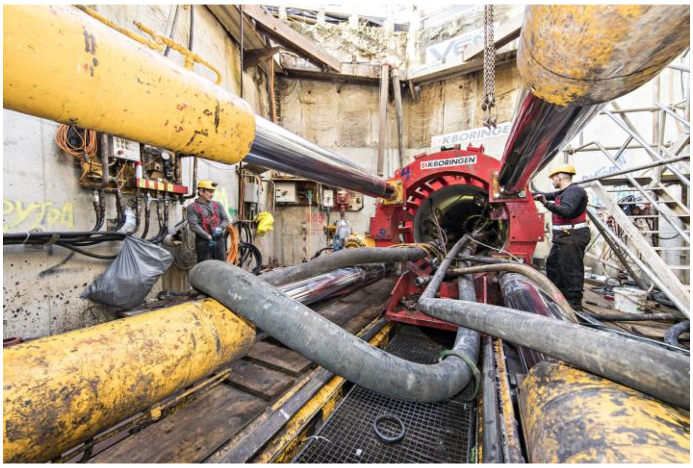
TEC preformed tender design services for the following elements of the Cooling Water System:

- Launching and reception Shaft
- Bored Tunnel
- System Hydraulic Design
- Velocity Cap structural design
- Chlorination dosing system details and Offshore Navigation Marker.

The details of the tender design were presented to Afcons for their submission in a concise design report, along with tender detailed drawings, specifications and quantities.

Blauwe Ader: Hasseltstraat - Midden Brabantweg

Project



To prevent flooding in the centre of Tilburg due to heavy rainfalls, the 'Blauwe Ader' (Blue Artery) was realized. This pipeline transports (rain) water from the centre to the border of the city. During the first 15 years after completion, both rainwater and first flush wastewater will be collected in the pipeline, which will be pumped out by a pump station to a Wastewater Treatment Plant (WWTP). After 15 years, the Blauwe Ader will act as a discharge pipe for rainwater which will be discharged in a waterpark. Only the first flush wastewater will still be pumped to the WWTP.

Diameter / Length:
DN 1.6m / 957 m
DN 1.8m / 2.360 m (900 m – 670 m – 790 m)

TEC's scope of work

TEC parent company Witteveen+Bos was responsible for:

- Alignment study based on a multi-criteria analysis;
- Collecting stakeholders' requirements;
- Drawing up an integrated contract based on the UAV-GC 2005 (D&C type of contract);
- Study micro tunnelling Rueckertbaan: drawing up sketch designs and cost estimates;
- Project management and coordination of the municipality of Tilburg and the construction JV / monitoring progress and planning;
- Contract and risk management (using Relatics);
- Managing contract management plan;
- Coordinate, organize, plan SCB (risk-based contract management) audits:
  - System audits;
  - Process audits;
  - Product audits;
- Assessment and acceptance final design and construction design. Associated expertise (not exhaustive):
  - Sewerage technology;
  - Above and below ground infrastructure,
  - Micro tunnelling;
  - Geotechnics: sheet piling, quay construction Wilhelmina Canal, grout anchors;
  - Cutter Soil Mix technique;
  - Construction technique: stamps, wells, underwater concrete;
  - Permits;

  - Dewatering;
- Process reports SCB tests;
- Assessing and advising contract mutations;
- Assessing and advising method statements.

CUT & COVER TUNNELS

General

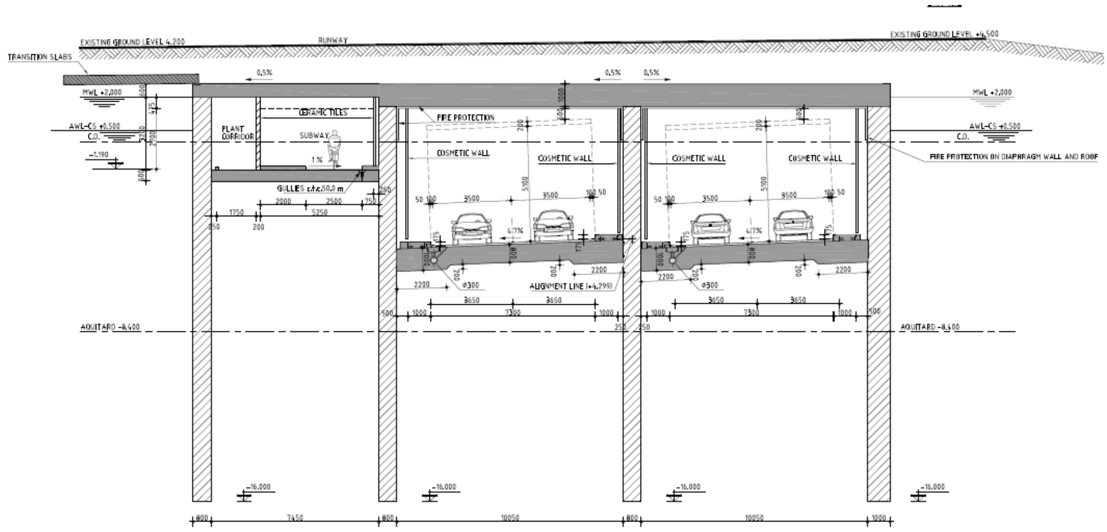
TEC, a permanent joint venture between Royal HaskoningDHV and Witteveen+Bos has been involved in the following cut & cover tunnel projects:

- Gibraltar Airport tunnel
- Freight traffic tunnel at Amsterdam Schiphol Airport, The Netherlands
- HOV-tunnel Zuid Tangent, The Netherlands
- Shindagha tunnel, Dubai, United Arab Emirates
- Markt-Maas tunnel, Maastricht, The Netherlands
- Stations in North/South Metro line, The Netherlands
  - Metro station Central Station
  - Metro station Rokin
  - Metro station Vijzelgracht
  - Metro station Ceintuurbaan
  - Metro Station RAI/Europaplein
- Tunnel Giessen, the Netherlands
- Gongbei tunnel, Zhuhai, China
- Nijverdal, the Netherlands
- Station Boxes Metro Red Line Tel Aviv – Israel
- Mexico City New International Airport
- Metro Arenastaden, Stockholm, Sweden
- Mexico City New International Airport APM tunnel

Gibraltar Airport tunnel

Project

The main tunnel will be a concrete structure comprising three bores (two road and one subway) separated by two walls. The subway comprises a lane for cyclists and pedestrians and one for plant corridor.
The tunnel is classified as Category B in accordance with BD78/99.
The length between portals is approximately 350 m on a 265 m horizontal radius.



TEC's scope of work

TEC provided the tender design for the Contractor, Volker Stevin Construction Europe.

Freight traffic tunnel at Amsterdam Schiphol Airport, The Netherlands

Project

As Schiphol continuous to grow, so does the need for proper freight handling. Schiphol Group initiated a new area for handling freight operations, and asked the Dutch Tunnel Engineering Consultants (TEC), in which Royal Haskoning participates, to provide a project study and design for a new freight handling area located just south-east of the runway 06-24.

To connect the new freight area with the centre of Schiphol, a tunnel was built. The tunnel has a width of 13 m and a total length of 850 m, with an enclosed tunnel length of 550 m.

The tunnel crosses the runway and two taxi-ways. At the northern entrance of the tunnel, a connection with an existing tunnel, running perpendicular, had to be constructed. In order to reduce the time in which the runway 0624 is not in use, in relation to construction costs, a number of construction methods were evaluated. Amongst these different methods, are the cut & cover method, an immersed tunnel, a bored tunnel, and the “wall roof” method.

The method that appeared to be the most suitable was the “wall roof” method. This is a method in which the walls and the roof of the tunnel are constructed first in order to restore the runway as soon as possible; after this, the soil in the tunnel is excavated and the base slab of the tunnel is constructed.

The walls are made up of steel tubes with sheet-piles in between (combi-wall). The roof is made with pre-stressed prefabricated beams and the base slab is made up of reinforced in-situ concrete.

TEC’s scope of work

TEC provided the feasibility study, cost estimates, design, contract specifications for a traditional and “design and build” contract. In addition, all services that were provided included electrical and mechanical installations.

HOV-tunnel Zuid Tangent, The Netherlands

Project

The tunnel is part of the cored part of the High-quality Public Transport Line Zuid-Tangent between Haarlem and Schiphol-east.
The tunnel has one tube comprising two lanes for busses or, in the future, two fast trams.
The tunnel crosses the new A5 motorway, the existing A4 and a taxiway of Schiphol Airport.
The approaches consist of open through concrete sections. The first 50% of the sections are build in the time the Zwanenburgbaan (a runway of Schiphol) was reconstructed and when the highway A4 was deflected for the building of a second train tunnel between Hoofddorp and Schiphol.

TEC's scope of work

TEC provided the following:

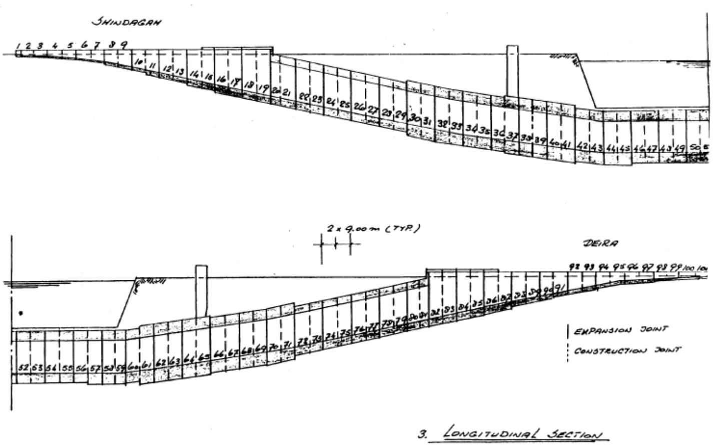
- Preliminary design and detailed design of the concrete works
- Tender documents and assistance to the client with the selection of the contractor
- Construction supervision

Shindagha tunnel, Dubai, United Arab Emirates

Project

The Shindagha tunnel in Dubai dates from the late 1970’s and consists of a 550 m long closed tunnel with approximately 200 m long open-ramp approach sections. The road tunnel accommodates 2 x 2 traffic lanes and has a third bore, specifically for pedestrians.
Shortly after opening, the tunnel already required substantial repairs and was fully renovated in the late 1980’s.

The Shindagha tunnel is a critical part of the Dubai road infrastructure and the owner / operator needed confirmation regarding the expected remaining life time of the tunnel.



TEC’s scope of work

TEC provided the Client with a remaining Life Expectancy statement for the tunnel, including recommendations regarding the maintenance of the structure.

TEC Tunnel Engineering Consultants

Markt-Maas tunnel, Maastricht, The Netherlands

Project

The project involved the inner-urban redevelopment of the area between the market and the western bank of the river the Maas in the city of Maastricht. The development consists of a four-storied underground car parking station, with a shopping centre and governmental offices above it.

Furthermore, a 400 m long under the Maas Boulevard is also part of the project. From this tunnel, underground facilities will be available for easy access to the shopping centre and the government offices. In addition, the tunnels will accommodate separate entry and exit lanes in and out of the car park. As a result, the middle section of the tunnel is constructed in two levels.

The Wilhelmina Bridge, that crosses the Maas at this location, needs to be modified and a new abutment on the western bank of the Maas, at the same level as the tunnel roof, is designed and constructed.

TEC's scope of work

For this project, TEC partner Royal Haskoning was responsible for all the designs and supervision during the realization of the tunnel and the adjustments to the bridge. This applies for the civil engineering as well as the tunnel technical installations designs; power supply, lighting, drainage, ventilation, fire safety, traffic signalling, communications and operations. Special aspects of the tunnel included its complex geometry, the unique geotechnical soil conditions which consisted of limestone and gravel, the position along the Maas, and the ventilation towers.

Stations in North/South Metro line, The Netherlands

Project General

To relieve the existing public transport system (bus, tram, metro and ferry lines) in and around Amsterdam, the existing metro system will be complemented by an additional 5th line, the North-South line. The new line is expected to provide transport for approximately 200,000 people a day. The first part of the line extends from the A10 ring road in Amsterdam North to the A10 ring road in Amsterdam South and has a length of 9.5 km.

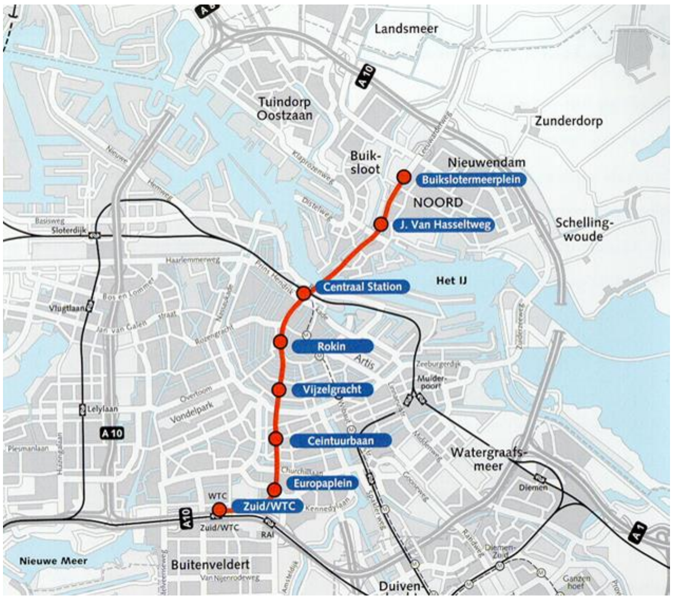


Figure Plan view with stations indicated

The line will be realised on ground level in the southern and northern parts, by way of an immersed tunnel where it crosses the river IJ, and by means of a 3.4 km long double tube bored tunnel to cross the old city centre. The new stations that make up the North-South line, three will be realised on ground level, one underground beneath an existing railway station, three deep underground stations will be constructed in the city centre, and one underground station at a relatively shallow depth. An innovative design approach containing special construction techniques was required, especially for the four stations in the city centre.

Stations' Design General

The North/South Line contains a number of designs based on advanced and innovative construction techniques that have to be applied within the historic city centre. Since application on this scale has never been applied before, a special design approach has been adopted for this vulnerable part of Amsterdam. This approach, in general, is valid for both the bored tunnel as well as the station boxes. An important starting point in the design process is a sturdy design; this means it does not only depend on advanced calculation models and is not sensitive to small variations in design parameters. Feasibility and parametric studies, with a focus on environmental impact, were carried out to develop this

sturdy design. In addition, all aspects of the design had to be completed and confirmed, which included the following:

- Extensive soil investigations including special tests that can accommodate data for the advanced calculation models that have been applied.
- Extensive desk studies to investigate building response (brick buildings on wooden pile foundations) to settlement induced deformations due to construction investigating the present state of the buildings alongside the alignment followed by a building classification, and in a number of cases suggestions for foundation reinforcement.
- Development of FE models considering the construction process for predictions and back analyses.
- A monitoring program to measure deformations of the buildings, subsoil and North/South Line structures (e.g. building pit walls).
- Development of back up measurements to implement in the design if anticipation on monitoring data is required.

Figure: Typical historic Amsterdam building and FE Model

- There was a lack of knowledge when applying the innovative design aspects; in these cases international recognised experts or institutes were consulted and the designs were reviewed. Furthermore, full scale tests were carried out to investigate the impact of construction techniques as a means of verifying and validating the calculation models that had been developed. The next set of tests that have been carried out are as follows.
- The test pile project to investigate the impact of tunnel boring activities to pile foundations.
- The environmental impact of diaphragm wall installation.
- The effect of grouting techniques (jet grouting, permeation grouting, compensation grouting).
- Freezing test.
- Test to investigate lining design.
- Tail injection test for the bored tunnel with a focus on limiting the environmental impact.
- This approach, based upon the observational method, was applied for several designs within this project, and fine tuned to a tailor made concept to meet the specific boundary conditions for each location.

Metro station Central Station

The North/South Line crosses underneath the central station of the Dutch Railways. The Central metro station is planned at this exact location. The platforms of the underground metro station are situated directly underneath the railway station and concourses and entrances are being constructed on both sides.

On the south side, a spacious concourse as well as entrances will be constructed underneath the Station Square, one of the busiest squares in Amsterdam. The building pit consists of 1.2 m thick braced diaphragm walls with lengths varying form 30 (building pit wall) to 60 m (building pit wall and foundation element). To limit the disturbance to city life a building pit cover will be installed in different stages. This deck is founded on bored piles and diaphragm wall panels with a length of 60 m. A jet grout prop is installed underneath the final excavation level to limit the deformations as much as possible. When the building pit was excavated to 22 m, the concrete structure was built incorporating the diaphragm walls into the permanent body.

On the north side, a concourse and metro entrances were built. The construction of this part is combined with the construction of a 2x2 lane traffic tunnel (passing over the metro) and a bus station platform at level +1. The building pit consists of braced combi-pile walls (diameter 1.6 m) and an underwater concrete slab (excavation will be carried out in the wet). After the excavation is completed the concrete structure, which is founded on bored piles with a length of 60 m, is built. In the construction phase the main building pit will also serve as a lock pit (in connection to the IJ river) for the floating transportation of a tunnel element (platform part) that is immersed underneath the railway station.

The platforms of this station are located underneath the railway station and are described elsewhere in this experience record (immersed tunnels).

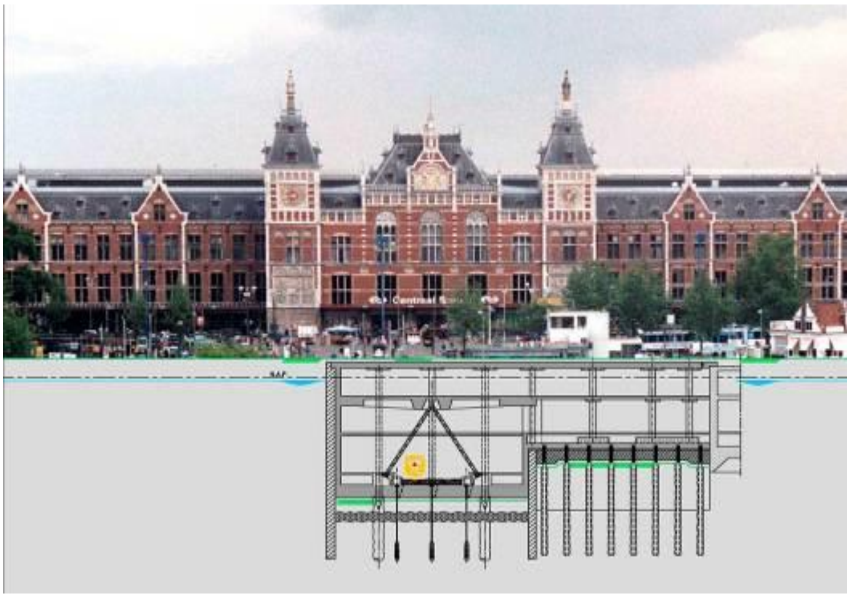


Figure: Schematic cross-section of the metro lines and entrance hall South Side

Metro station Rokin

Metro Station Rokin is located in the city centre, just south of Dam Square and has been designed for a daily capacity of 60.000 passengers.

The project comprises of a 190 m long metro station with the platforms at a depth of approximately 22 m. Located on top of the station, is a 5-level parking garage, bicycle parking, as well as a water clarifying and storage basin. Access to the station is provided through two entrances, one at the northern end and one at the southern end of the station. These entrances give access to the underground entrance halls that lead to the platform.

The station is constructed using the wall-roof method where the walls are realized by means of the diaphragm wall technique and several prop layers, a deep jet grout strut is provided to limit environmental impact. This construction technique is applied to minimize the impact of the construction on its surroundings. The 40 m deep diaphragm walls are being constructed at close distance from the existing buildings; the building pit will have a final excavation level of 26 m below ground level which requires a high level of deformation prediction and is tested in relation to the continuous monitoring that takes place during construction. The impact of installing diaphragm walls close to buildings was tested by means of a full scale test, which included the development of a 3-dimensional Finite Element model for predicting specific locations in Amsterdam.

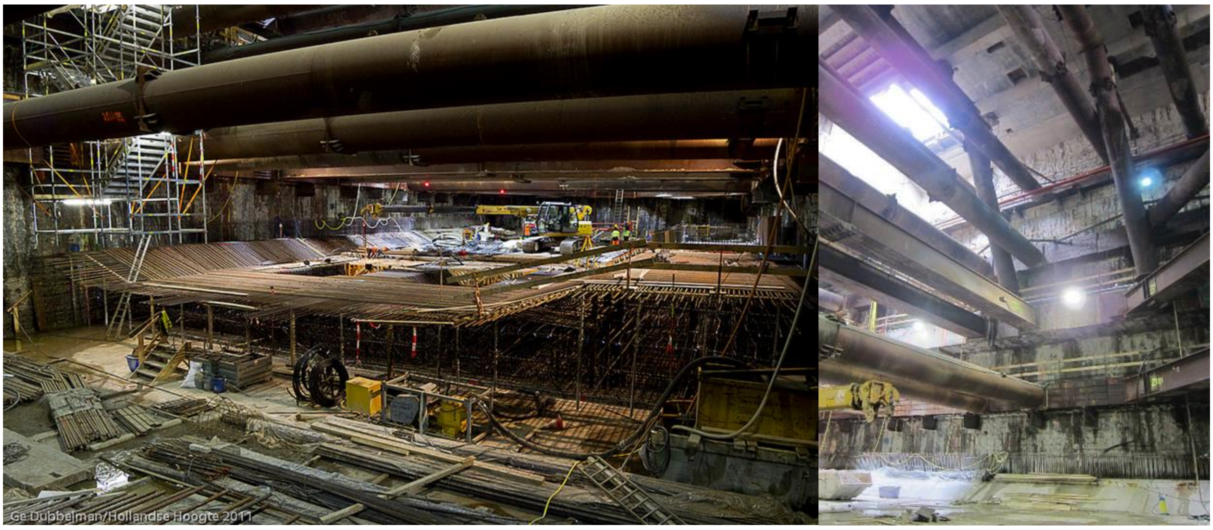


Figure : Construction of base slab at 26 m(left) and impression of building pit (right)

Metro station Vijzelgracht

Metro Station Vijzelgracht is located in the city centre and has a total length of approx. 260 m; the platform will be at a depth of about 26 m and some 30,000 passengers are expected to use this station each day. The station will have three entrances.

In the space above the underground station, a so-called detention-and-settling tank will be created to serve as an overflow area for excess rainwater drainage. There are plans for underground parking facilities for both cars and bicycles in the future.

Figure Rendering longitudinal section of Vijzelgracht station

The station is constructed applying the same methods as used for Rokin Station. Since the excavation level was approx. 32 m, the stability of the base of the deep part of the excavation had to be secured using compressed air conditions.

Figure: Impression of excavation deep part of the building pit under compressed air conditions.

Metro station Ceintuurbaan

Ceintuurbaan is the southernmost metro station in the city centre. It is located in the very narrow Ferdinand Bolstraat, for which reason the station has been accommodated with stacked platforms. This allowed for the narrowest possible station lay-out. The consequence however was a very deep station with platforms at 16.5 m and 26.5 m respectively and an excavation level of over 32 m. This station has two entrances and is supposed to allow for some 35,000 passengers per day.

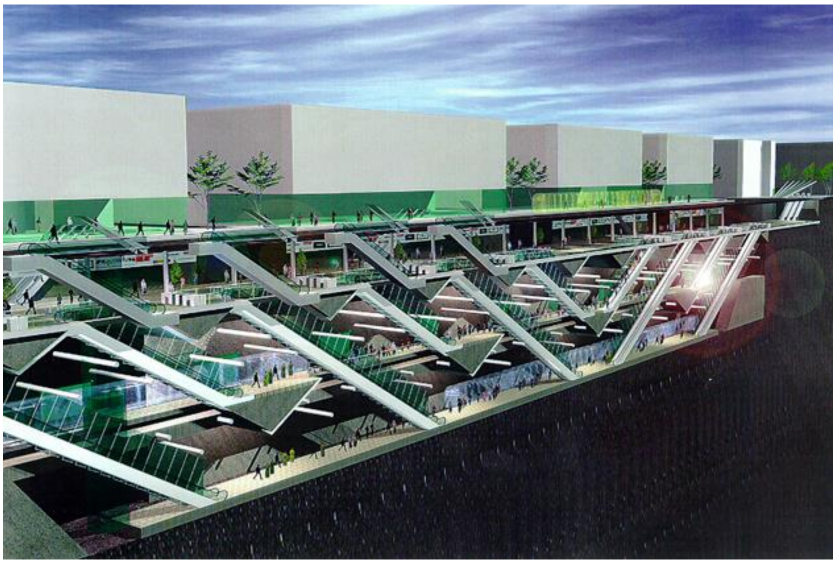


Figure: Rendering of station

The station is constructed applying the same methods used for Rokin and Vijzelgracht Station. As for Vijzelgracht Station the deep part of the excavation had to be carried out under compressed air conditions.

Figure: Diaphragm wall construction

Figure: Station under construction

Metro Station RAI/Europaplein

Metro Station RAI/Europaplein is one of the 8 stations of the North/South metro line in Amsterdam and located at the southern side of the line in front of the Amsterdam exhibition centre RAI. The station has been designed for a daily capacity of 27,500 passengers.

The project comprises of a 200 m metro station as well as two adjoining tunnels, one north of the station measuring 235 m, and one south of it, measuring 270 m. The tunnel sections and station are below ground level and were realised using the cut-and-cover construction method.

The construction pits consisted of steel sheet-walls with girders and struts, and an underwater concrete floor with tension piles. A reception shaft was made for the 2 tunnel boring machines which were used to bore the tunnel sections under the city centre, as well as for the emergency exits. The reception shaft is located at the northern end of the project site, at this location the construction pit will reach a depth of approximately 20 m, and the northern tunnel will gradually rise to a depth of 9 m and the southern tunnel will rise to a depth of 7 m.

Access to the station is provided by two entrances which lead to underground distribution areas and is equipped with extensive safety systems in case of an emergency.

Figure: Tunnel under construction

Figure: Main civil works for Station completed

TEC's scope of work for the North South Line Stations

As the Lead Consultant for the Client (the Municipality of Amsterdam), the TEC partners were responsible for the integral design (involvement since 1994). During the initial stages, the Reference Design was developed, followed by the pre-design, final and detailed designs, drawings and technical specifications, tender documents, consultancy regarding the contracting strategy, contract administration, construction supervision, as well as the preparation of procedures and guidelines for project monitoring, assistance with the public consultation and permit process, risk management, construction safety and environmental issues.

Tunnel Giessen, the Netherlands

Project

A railway tunnel running under the Giessen, is one of the structures designed as part of the “Betuweroute.” The Betuweroute is the newly dedicated freight railway line, measuring a length of 160 km, stretching across the Netherlands and linking Rotterdam’s busy port to the existing German rail network.
In this particular location in Giessenlanden, the Betuweroute does not follow the path of the existing infrastructure within the area, which consists of highway A15 and the railway Dordrecht-Geldermalsen, but instead its location is more to the North to spare the buildings located in the area. To cross the river Giessen, a tunnel with two separate tubes was built in a construction pit. In an earlier planning stage, a preliminary design was made for a bridge to cross the river, but due to environmental aspects, a tunnel was chosen instead.

The tunnel consists of a covered part with a length of 500 m which is located directly under the Giessen. There is an open access ramp located on both sides of the tunnel. The access ramp on the west side has a length of 490 m and the east side ramp has a length of 400 m.
During construction, the water drainage as well as the shipping on the river de Giessen could not be interrupted, therefore the construction was carried out in two stages. In the first stage, the west side of the tunnel was built, but only half way across the river so that water drainage and shipping was still possible. After completion of the west side of the tunnel, the construction pit was moved to the other side, enabling the construction of the east side to be made.

Figure: Tunnel under the Giessen under construction

TEC’s scope of work

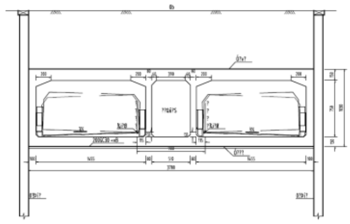
TEC has been involved through its partner Royal Haskoning who carried out the feasibility study for this project, as well as the preliminary design, final design, and the write-up of tender documents

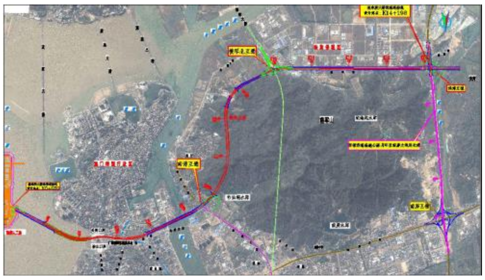
Gongbei tunnel, Zhuhai, China

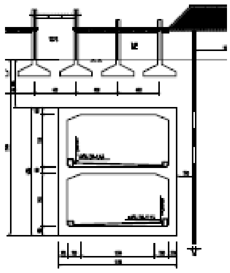
Project

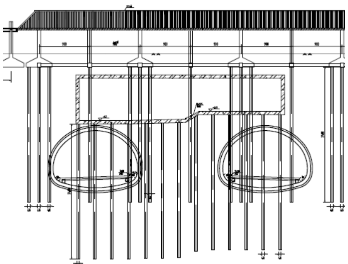
The Hong Kong – Zhuhai – Macau Bridge (HZMB) Fixed Link project provides for a fixed link between the two economic centres Hong Kong and Macau (both of which are Special Administrative Regions within PR China) and the mainland of China at Zhuhai. The whole link, which measures some 50 km in length, has been divided into several major sections. The Zhuhai Link has a length of some 14 km and consists of a bridge that runs from the Zhuhai-Macau BCF island towards the mainland where it converts into a tunnel underneath the Gongbei Border Crossing Facility. It surfaces further to the west to cross the Qian-shan-River and Nan-Wan Road in the form of bridges, and then travels southward as a tunnel through the Nan-Ping Mountain. The final stretch that runs in western direction consists of viaducts with connections to the Heng-Qin North interchange and Hong-Wan interchange.

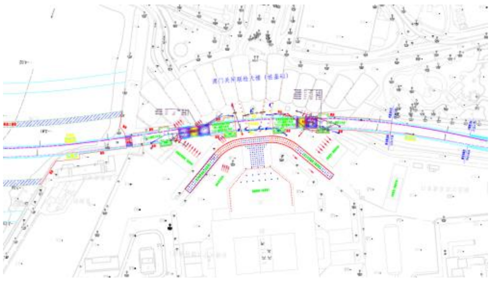
The Gongbei Border Crossing Facility is one of the busiest facilities of its kind in China, which puts specific challenges to the realisation of a 3-lane dual carriageway underneath it.

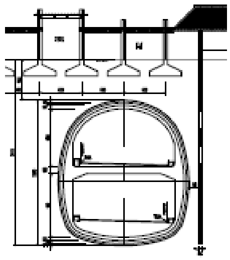












TEC's scope of work

TEC has performed a risk assessment including the definition of possible risk control measures for design scheme and construction organization for three different alignments. One alignment considered a single layer tunnel to be realised using the open excavation top-down method, another alignment also considered a single layer tunnel but then to be realised using the subsurface excavation method. The third alignment considered a double layer tunnel that was to be realised using the open excavation method with selected lengths using the subsurface excavation method and applying complex pipe-jacking methodology for the tunnel perimeter combined with freezing techniques for water tightness during the execution of the works.

The Risk Assessment was carried out in compliance with the Chinese ”Risk Assessment Guidance for Highway Bridge and Tunnel” (Version for trial) complemented by International accepted Risk Assessment Methodologies. In the assessment, aspects such as project development and implementation, construction conditions, structural concepts, construction technology and operational management were addressed.

Specific issues include:

- Interference with Gongbei BCF operations (health, safety & security)
- Close proximity to BCF facilities
- Unfavourable sub-surface conditions
- Deep construction
- Tunnel Safety
- Risk Management practices in China

Nijverdal, The Netherlands

Project

The center of Nijverdal is one of the last city centers in the Netherlands that is split in two by a national highway/railway. This obviously has a detrimental effect on the livability, traffic flow and traffic safety in the Nijverdal center. To improve this situation, the city council, together with the Dutch Ministry of Transport and Public Works have initiated the “Combiplan” project that aims at abandoning the through traffic from crossing the city center.

The Nijverdal Combiplan project includes a 400 m long tunnel section, with an open-tunnel section and approach ramps on both ends. The tunnel will accommodate 2 x 2 traffic lanes, each of which will be in a separate tube. The tunnel will also accommodate the double track railway line.

The entire project also includes all associated works on the surface and is realized under Design & Built. The contractor for the project invited Royal Haskoning/TEC to provide the structural design for the road and railway tunnel. Royal Haskoning/TEC has undertaken this assignment using System Engineering methodology.

TEC’s scope of work

The consultancy services to the D&C Construction included:

- Tender design
- Detailed design

Station Boxes Metro Red Line Tel Aviv – Israel

Project

NTA, a government owned special company acting as the Client, is developing a Light Rail Network in the dense populated area of Greater Tel Aviv. In this area approximately 2.5 million people (1/3 of Israel’s population) are living and working. The first line to be constructed is the Red Line, running from the North-Eastern part to the South-Western part of Greater Tel Aviv. This line has a length of 22 km, of which 10 km underground.

TEC Partner, RoyalHaskoningDHV (RHDHV) has formed a joint venture with IBI (a Canadian architectural firm) for the design of the ten stations in the underground section of the line. The underground section is running through the municipalities of Bnei Barak and Ramat Gan in the North East and underneath the city centre of Tel Aviv in the South West. The tunnel is designed as a bored tunnel. The stations are designed with D-walls and a temporary deck for traffic. The stations will be constructed “Bottom – Up”.

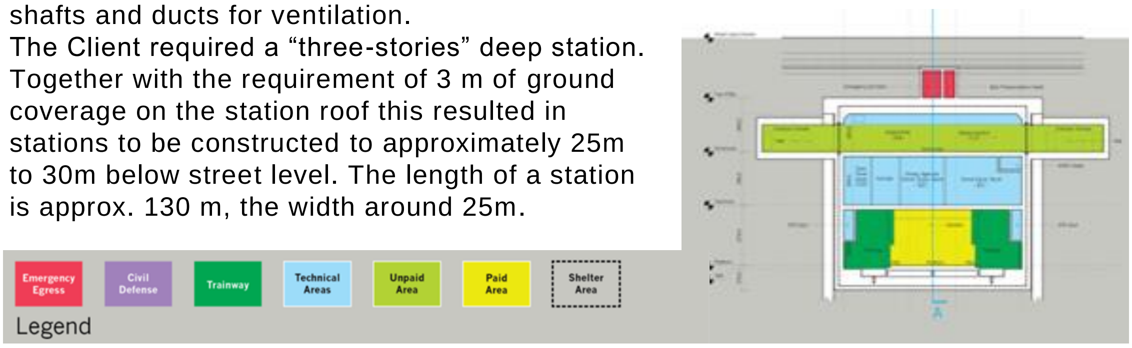
The Client originally had the idea to contract the underground part of the Red Line as a Design – Build project. During the conceptual design of the stations the Client decided that the stations should be contracted in a Design – Bid – Build Contract. This caused a significant change in the Design Contract for the Design Joint Venture.

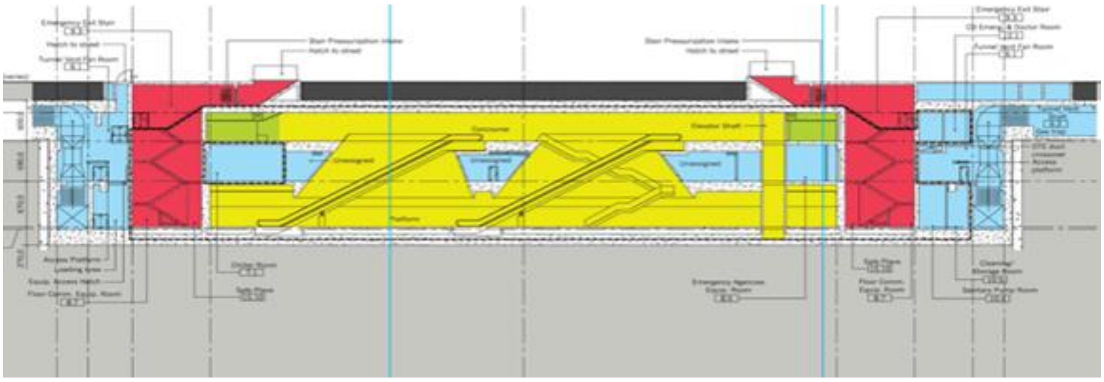
Stations’ Design general

Besides the functionality as a station, for passengers, the stations had to be designed as bomb shelters. This caused additional requirements for a.o. blast doors in order to make the station safe for explosions. These blast doors are

foreseen in the entrances, the bored tunnels entering the station and further all shafts and ducts for ventilation.

The Client required a “three-stories” deep station. Together with the requirement of 3 m of ground coverage on the station roof this resulted in stations to be constructed to approximately 25m to 30m below street level. The length of a station is approx. 130 m, the width around 25m.





For reasons of controlling the climate and passenger safety the Client required to design for Platform Edge Screens. In this way the trainway is physically separated from the platform thus creating a comfortable climate on the platform.

The station boxes will be constructed by means of D-walls (as an outer box) and later the station will be constructed within the D-walls (as an inner box). All these construction activities are taking place in the densely populated area of Tel Aviv. The traffic may only be partially interrupted. Therefore a temporary traffic deck is foreseen on top of the D-walls. Under this traffic deck the construction of the

inner box will take place. The temporary traffic deck will also be used for the temporary hanging of ongoing utilities.

The D-walls together with the excavation will cause settlements of the surrounding area and buildings. After having defined an additional Soil Investigation programme a detailed report on the Zone of Influence has been produced before obtaining the building permits.
Complicating aspects/requirements in the design were:

1. quantity of water to be extracted from the bottom
   due to the limited quantity of water which might be pumped away the excavation had to be designed as a “wet-excavation”. This required the application of underwater concrete
2. tie-backs or horizontal ground anchors were not allowed
   due to the fact that the adjacent buildings are private owned the Client did not want to take the risks for legal delays with arranging the right for installation of the ground anchors. Therefore the design had to apply struts and girder beams
3. the ongoing traffic
   due to the limited space for the various construction stages sometimes four or five stages had to be applied for the construction of the outer box. This had to be combined with the same number of traffic diversions and relocation of utilities. Thus resulting in complicated permitting arrangements with all stakeholders.

The design joint venture is responsible for the design. However the majority (80%) of the structural and foundation design was executed by local sub-consultants (as is the case for the M&E as well). The joint venture kept the tasks of managing the process, reviewing the designs, advising on strategic level for 3D-geotechnical calculations, geo-hydrology, special techniques like underwater concrete and RAMS-aspects.

TEC’s (RHDHV) scope of work

Within the joint venture (IBI/RHDHV) RHDHV is the lead consultant (and ultimate responsible) for the integrated design of the five underground stations in the municipality of Tel Aviv. The design comprises the conceptual design, the preliminary design, the final design, the tender design and the detailed design inclusive of the construction documents. Next to these design works RHDHV will also be involved in the supervision of the Works. Since the services covers the integrated design the following disciplines were supplied by RHDHV: structural, geotechnical and M&E design, as well as the management thereof and the management over the disciplines architecture, traffic diversions, utility relocation and road restoration. Also the permitting process with the municipality formed a part of the scope.

Since approximately 80% of the services were executed by local sub consultants a major task was in managing the various subconsultants. Each station had its’ own “set” of subconsultants, therefore RHDHV had to manage multiple contracts with these sub consultants. A dedicated team (of both Dutch and Israeli people) worked close together. As a result of bringing together various subconsultants with a same technical discipline advantages in the design process were achieved like a uniform design of e.g. the blast doors, the grounding system or the water proofing concept.

Mexico City New International Airport

Project

The new airport will replace the Mexico City International Airport, which is at full capacity. The new airport will have three runways to start and will be expandable to up to six runways. With three runways in simultaneous use the airport will be able to serve up to 50,000,000 passengers per year. The site for the new airport is located to the east of Mexico City. It is positioned within an area that was formally covered by Lake Texcoco; the lake has now dried up but the resulting ground and groundwater conditions are challenging.

The design of the tunnels is challenging due to the soft soil conditions, heavy airplane loads crossing the tunnels and severe seismic conditions. Although the desired longitudinal stiffness to spread airplane loads is not compatible with the desired flexibility to absorb seismic surface waves an optimal joint distance was proposed by TEC.

By deep ground water extraction the settlements amount 150mm per year. To limit differential settlements in the taxiways crossing the tunnel the weight of the tunnels is 100% balanced with the surrounding soil .To further limit potential differential settlements a transition zone next to the tunnels is developed (one of multiple mitigation measures). The transition zone consists of geotextile encased tezontle piles. The safety concept and MEP design was also developed by TEC.

Seismic study:
The study contains the results of a seismic response analysis. The execution of a site specific seismic response analysis was recommended because of the special soil conditions. The seismic input data for the calculation consist of carefully selected recorded earthquake signals, which are scaled to match the expected hazard spectra.

With the data from the seismic studies the effect on the tunnel in transverse and longitudinal direction was studied. For the longitudinal direction a special FEA model was developed to study the effect of the large seismic displacements on the joints of the tunnel.

Tunnels:

- Two Ground Service Equipment (GSE) tunnels with a length of 1300m. The GSE tunnels will be used by airport busses, catering trucks and tow-vehicles.
- Two airport utility tunnels parallel to the GSE tunnels.
- A public road tunnel used by supply trucks, passenger cars and busses carrying employees to the Support Area.
- A third GSE tunnel to connect the Maintenance Area with the Airport Support Area and Cargo.

TEC's scope of work

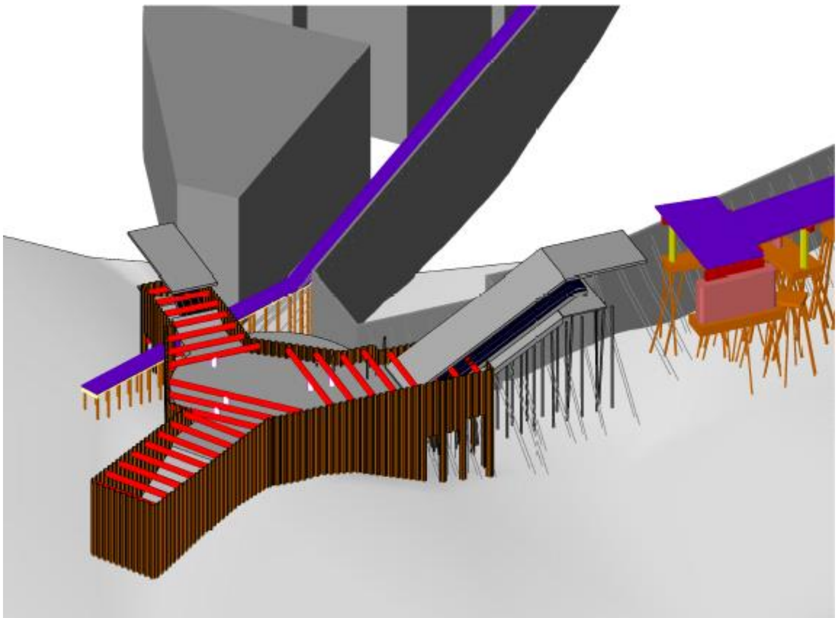
TEC is a sub consultant for the NAICM project and is responsible for the tunnels and the seismic studies during the conceptual and final design phase of the project. Support and checking is provided in the detailed design phase. The tunnels in the project are constructed with the cut & cover method.

Metro Arenastaden, Stockholm, Sweden

Project

TEC was involved in the extension of the Stockholm subway project, TUB A. The TEC design team worked in close collaboration with WSP who was the main consultant for this project. TEC was involved in the design of the Northern ticket hall of station Arenastaden for the System Handling Phase. The station will connect Stockholm's existing underground network to new developments in the Solna area, including the stadium (Arena) and Mall of Scandinavia.

Most of the alignment of the extension is situated in hard rock, the northern ticket hall of Arenastaden is in soft, sensitive clay up to 16 m deep. For this reason specific geotechnical and structural expertise from within TEC was involved. We started with an integrated team within WSP with several options for this construction pit. Based on the trade-off TEC made, an architecturally pleasing circular ticket hall was selected. The pit has a proposed diameter of approx. 40 meters and a depth of 15-20 meters (up to the hard bedrock). The connection to the metro station and the surface level is made through escalator shafts within rectangular pits.



TEC's scope of work

TEC contribution to the design was:

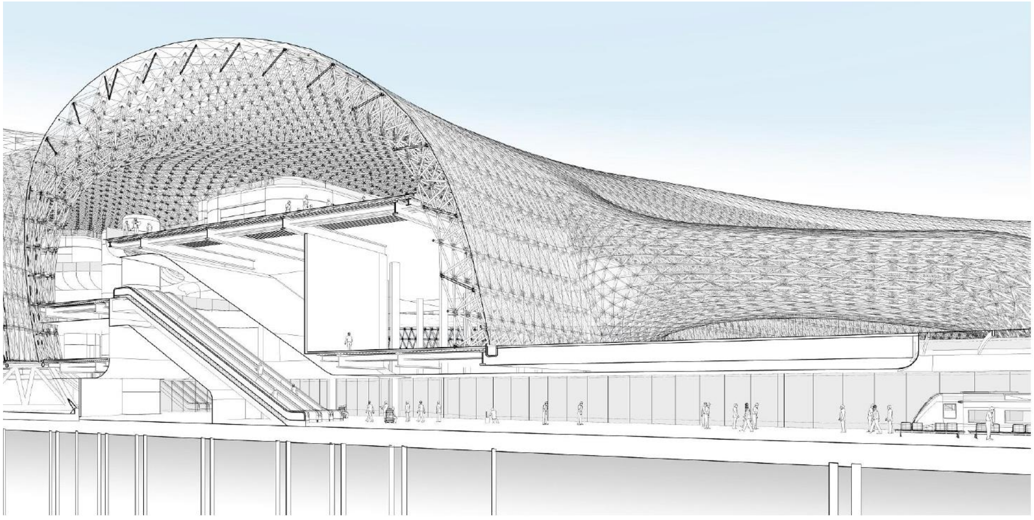
- Structural and geotechnical design by the use of PLAXIS
- Design drawings in REVIT

For this purpose, TEC worked close together with the design team of WSP in Stockholm.

Mexico City New International Airport APM tunnel

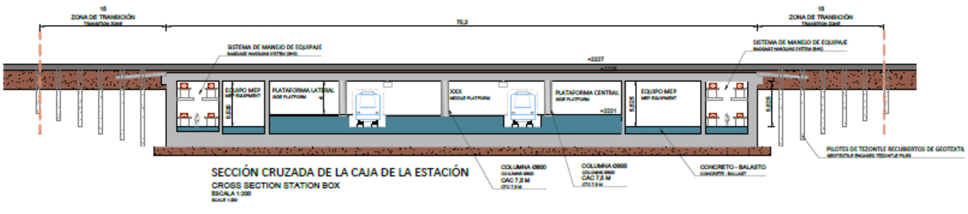
Project

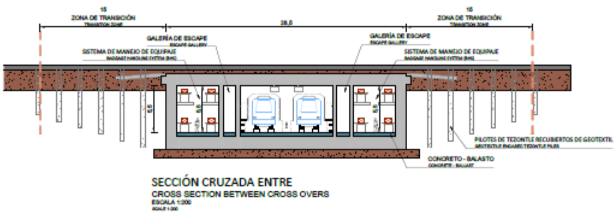
The new airport will replace the Mexico City International Airport, which is at full capacity. The new airport will have three runways to start and will be expandable to up to six runways. With three runways in simultaneous use the airport will be able to serve up to 50,000,000 passengers per year.



During the design phase of the project a new masterplan was issued by the client due to the increase in the air traffic forecast. This new masterplan requires the first satellite building to be operational in 2030 including an APM connection with the main building. The purpose of this study was to check the feasibility of building the tunnel on an operational airside. For the feasible solution the construction method and phasing has been analysed to study the impact on airport operations.

The construction phasing and the impact on the design of the APM tunnel and the connection to the terminal and satellite buildings and the transition from the tunnel to the aprons are challenging due to the soft soil conditions, heavy airplane loads crossing the tunnels and severe seismic conditions.





TEC's scope of work

TEC was sub consultant to NACO for the NAICM project and responsible for the APM tunnel design including a construction phasing that would be appropriate for the tunnel operation and would address complicated connections to other new and to existing structures, considering the challenging ground and seismic conditions.

Amongst others TEC defined the minimum required construction space and phasing. NACO looked at the operational aspect (aircraft stand demand and aircraft routing). After an iterative process, this resulted in two main scenarios. These scenarios were further developed for detailed tunnel segment construction planning, operational clearances and taxiway routing scenarios, construction traffic access, availability for construction site offices/lay down areas and cost implications. A final check on stand availability of aircraft stands and the requested aircraft stand demand was performed. The outcome were two realistic construction scenarios for the APM tunnel construction in an operational airport situation. The financial, operational and construction time impact were identified for client decision-making.

OTHER TUNNELS AND RELATED STRUCTURES

General

TEC and its partners have been involved in various other tunnel projects, a selection of which has been provided below. The projects include various jacked and pulled tunnels, pneumatic caissons, NATM tunnels, aqueducts, underpasses and other.

- Amsterdam metro tunnel Damrak, the Netherlands
- South taxiway tunnel, the Netherlands
- Motorway 37 underpass “Erica”, The Netherlands
- Underpass Taxiway Schiphol Airport, The Netherlands
- Aqueduct Grouw, the Netherlands - 1992
- Aqueduct Vliet, the Netherlands - 1996
- Aqueduct Gaag, The Netherlands - 1998
- Aqueduct Alphen, the Netherlands -1998
- Naviduct Krabbergatsluis, the Netherlands
- Aqueduct for Canal through Walcheren, The Netherlands - 2010
- N31 Aquaduct Harlingen, the Netherlands

Amsterdam Metro tunnel at Damrak, The Netherlands

Project

At the “Damrak”, situated near the Amsterdam’s “Centraal (railway) Station”, a part of the North/South metro line will be constructed using the pneumatic caisson method. The project comprises a total of 3 caissons providing a total tunnel length of 150 m. Along this section of the metro tunnel, the rail track will vary in depth between approximately 18 m at the northern end and 22 m at the southern end.

The construction technique selection for this location was highly influenced by the underground condition including the presence of large obstacles, such as the presence of three municipal bridges, the many complex traffic flows of regular traffic made up of cars, bicycles, and pedestrians, as well as traffic generated by trams, busses and sightseeing boats and possible remains from the past (ancient quay walls, sunken ships etc). The selection was also affected by the presence of the main high-water barrier functionality at this part of the alignment.
Further evaluation indicated the need for three caissons with different dimensions. The most southern caisson is the largest and includes a movable gate that can be closed in case of a flood in the tunnel section under the river IJ. This caisson also doubles as the starting shaft for the two tunnel boring machines that will realize the 3.8 km long bored tunnel section of the North/South line.

Figure Impression of the pneumatic caisson design and construction

TEC's scope of work

The TEC partner Royal Haskoning, through its partnership with Adviesbureau Noord/Zuidlijn V.O.F. (in which the TEC partner Witteveen + Bos also participates) provided the required engineering consultancy services for this project including the structural design, engineering, the preparation of the tender documents, consultancy regarding the contracting strategy, as well as the contract administration and construction supervision

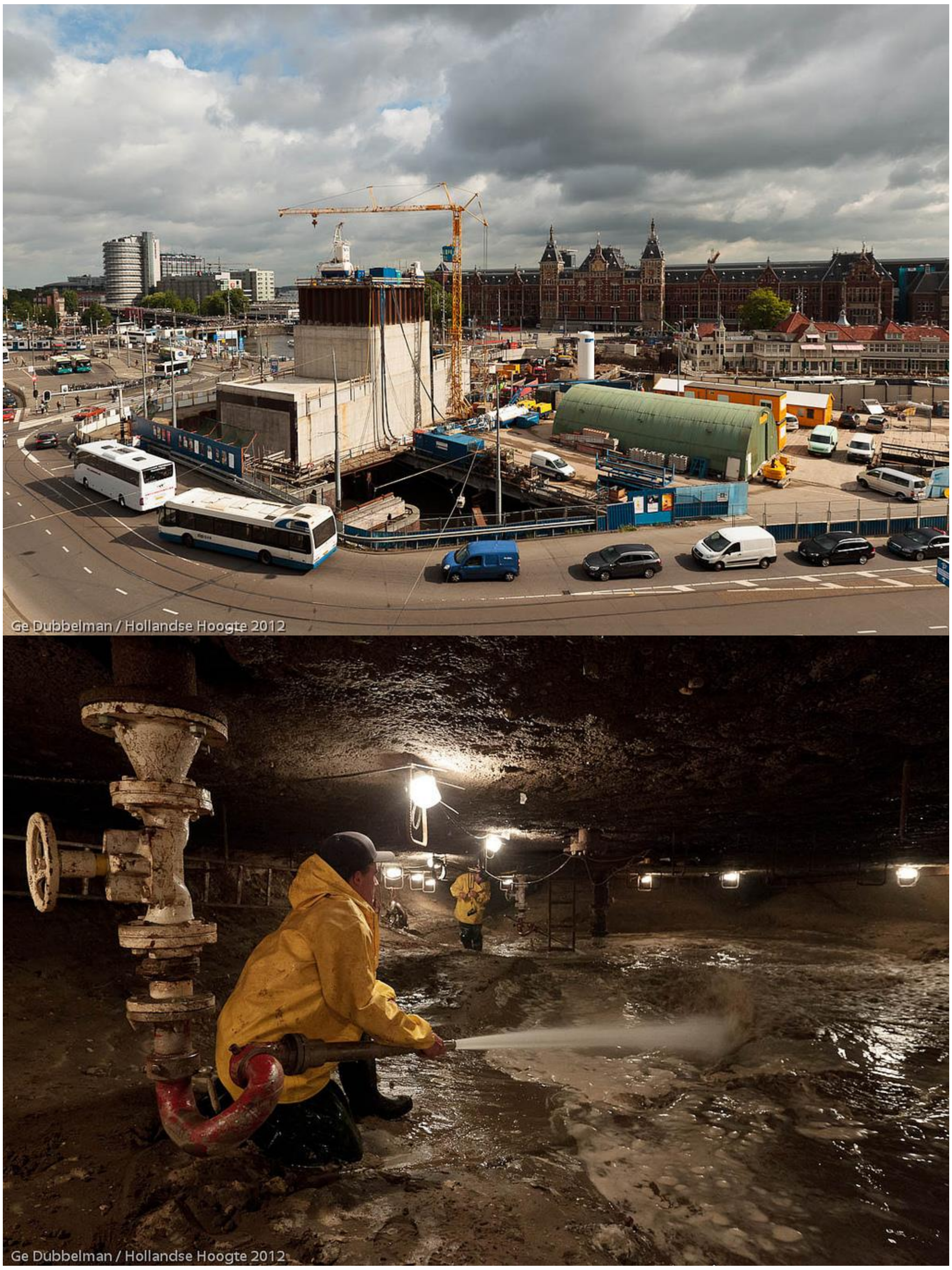


Figure Caisson at surface level (top) and excavation below caisson (bottom)

South taxiway tunnel, The Netherlands

Project

The project concerns the crossing of the south taxiway to the 5th lane on Schiphol with the to be constructed Verlengde Westrandweg (A5).
The A5, consisting of 2 roadways with each 2 lanes with a hard shoulder, will for this purpose be constructed with a length of approximately 1100 m in a deep tank-construction.
On the south roadway approximately 160 m will be constructed as a closed tunnel. They will reckon with the possibility for a second roadway for satellite traffic in the future.

TEC's scope of work

TEC provided the preliminary and final design for the civil structures as well as for the technical installations.

Motorway 37 underpass “Erica”, The Netherlands

Project

The project concerns a new underpass for 2 lanes of road traffic. The existing national road N37 will be transformed to a highway (2*2 lanes). The existing road will be the future Southern part of the highway. Just north of the existing road, the new road is foreseen.

One of the new structures in this road is the KW-13N. This is an underpass, next to the existing structure in the southern road (KW-13Z) near Erica. The local road, the “Ericasestraat”, will cross over the new highway via a fly-over in the middle of the underpass.

The underpass will be built in an open trench with drainage. At the intersection with the “Ericasestraat” the excavation will be carried out with sheet piles. At the deepest level the water cellar will be constructed.

The crossover is made of pre-cast box-girders founded on the sheet piles.

TEC’s scope of work

TEC provided the civil tender- and detailed design:

- Tender documents and drawings.
- Design calculations.
- Geotechnical and geohydrological calculations and advisory.
- Structural design calculations and drawings.
- Back-office during construction period and review of calculations executed by contractor.

Underpass Taxiway Schiphol Airport, The Netherlands

Project

The project concerns the crossing of the south taxiway to the 5th runway on Schiphol with the Hoofdvaart in the Haarlemmermeer and the roads, which run parallel. These roads are therefore U-shaped concrete structures (open through). The fly-overs for the taxiway and the parallel service road are designed as pre-stressed concrete structure, cast in-situ.

TEC's scope of work

TEC provided for the preliminary design and final design, detailed design and construction supervision.

Aqueduct Grouw, the Netherlands - 1992

Project

The Ministry of Public Work in the Netherlands commissioned TEC partner Royal Haskoning to design an aqueduct in Grouw, located in the north of the Netherlands.
The tunnel was built to enable the uninterrupted crossing of a highway with a major shipping channel.

The aqueduct is made up of 3 tunnel tubes, 2 tubes for road traffic and one smaller tube for slow traffic. The two traffic tubes are approximately 8 m wide and 4.5 m high and the slow tunnel tube is approximately 3.5 m wide and 3 m high.

After creating a large deep trench on either side of the channel with sheet piling and membranes, the tunnel section was constructed in dry conditions at the location of one of the access ramps. The foundations for the tunnel and the ramps on either side of the channel were built simultaneously, where as the tunnel section was made buoyant; it was floated and lowered into its final location. Although built in-situ, the disruption of traffic for both highway traffic and shipping never exceeded a period of 24 hours.

Figure: The Aqueduct in operation

TEC's scope of work

- Detailed design of the tunnel sections, the sub-structures and tunnel foundation.

Aqueduct Vliet, the Netherlands - 1996

Project

The Hague-city is connected with the A4 motorway, by the A14 motorway crossing the navigable canal Vliet. This crossing will be a tunnel part with an aqueduct, both concrete structures. The approaches are open concrete structures. The tunnel is 40 m wide and the length of the structure is more than 500 m.
The tunnel is a combined road-tramway tunnel. The structure will be 40 m wide.

The secondary road along the canal crosses the approach by a viaduct. The structures are to be founded on tensile piles because of the high ground water level. The tunnel and the approach will be constructed between sheet piles, the bottom of the trench being watertight covered with an underwater concrete floor. So the groundwater level will not be affected by the works. The ship canal will be temporarly diverted and the tunnel/aqueduct will be constructed in two phases

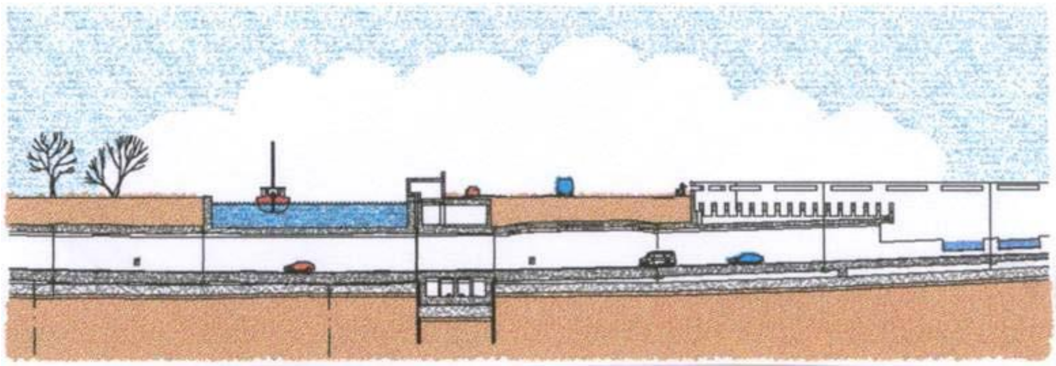


Figure: Sketch of the Aqueduct

TEC's scope of work

- Preliminary design
- Structural computations
- Design drawings
- Design report
- Cost estimates
- Construction schedule including alternative option

Aqueduct Gaag, The Netherlands - 1998

Project

The A4 motorway crosses the Gaag River with a 600 angle. The 40 m wide road tunnel is constructed as an aqueduct in the Gaag River. The aqueduct consists of a through shaped pre-stressed concrete structure. The approaches are open concrete structures.

The total length is 380 m. The secondary roads along the Gaag River crossing the approaches are constructed as viaducts.

The tunnel part and the approaches are founded on tensile piles because of the high groundwater level. The ship canal is temporary diverted and the aqueduct is constructed in phases. The building pits are partly surrounded by steel sheet piles limiting the effects of the temporary lowering of the groundwater level.

Figure: © Beeldbank Rijkswaterstaat

TEC's scope of work

- Final design, design report considering alternatives
- Structural computation and design drawings
- Review of tender documents
- Detailed design comprising structural computations and detailed drawings
- Review of contractors design documents
- Design and contract specifications for the electromechanical installations
- Advice upon construction

Aqueduct Alphen, the Netherlands -1998

Project

To improve the infrastructure along the Oude Rijn a new main road between Leiden and Bodegraven will be constructed. Near Alphen aan den Rijn the river Gouwe will be crossed by an aqueduct. The aqueduct consists of an immersed pre-stressed concrete element under the Gouwe, with on both sides an open through construction, at the end changed in a “polder construction”.

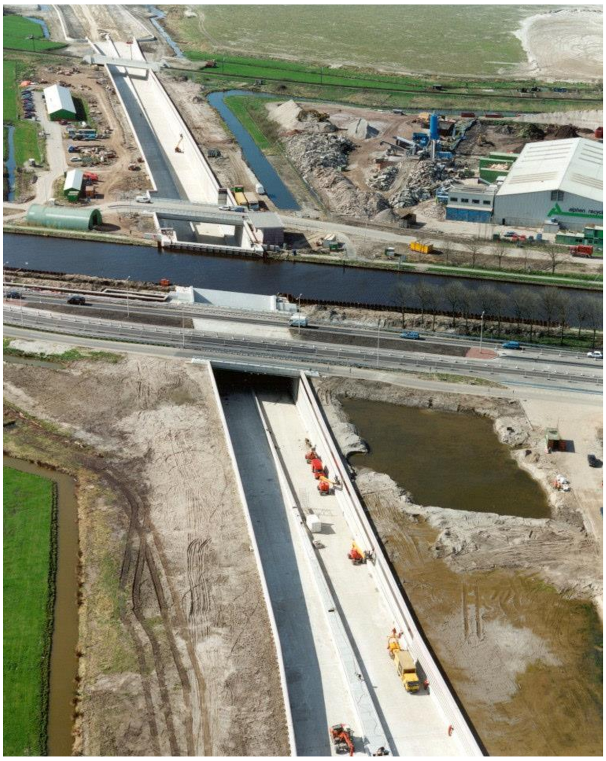


Figure: Aquaduct under construction

TEC’s scope of work

TEC has provide detailed design of the Civil and Structural works and site supervision during construction.

Naviduct Krabbersgatsluis, the Netherlands - 2002

Project

In the existing dike between Lelystad and Enkhuizen lies an existing lock named Krabbersgatsluis. This lock crosses the road that is situated on top of the dike by means of a draw-bridge. In de holiday season the junction between the road and waterway is a source of congestion for road traffic because the lock is used for private yachts without having their masts stroked, causing a high frequency of opening of the bridge. For navigation the lock is also an obstacle because the passage capacity is not in proportion with the traffic volume which leads to an extended wait for navigation. To avoid congestion a choice is made for a crossing where the road is led under the waterway. The existing lock will be kept in operation for professional barges only. Because the height of the barges is limited passing the lock will not claim frequent openings of the bridge. The new lock has been constructed on a new artificial island made on the southern side of the dike.

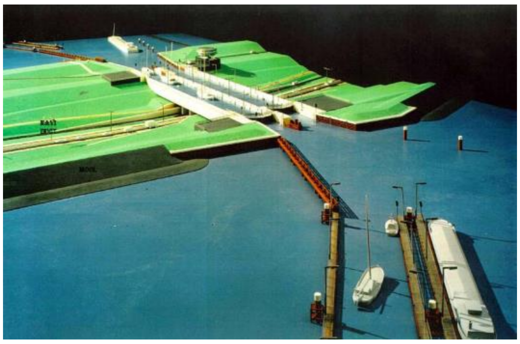


Figure: Rendering of Naviduct

Figure: Naviduct completed (source VBK Groep)

TEC's scope of work

Civil and structural works:

- Preliminary design
- Final design
- Contact drawings
- Contract
- Pre-qualification of contractors
- Tendering of the project
- Evaluation of the bids
- Assistance on supervision

Aqueduct for Canal through Walcheren, The Netherlands - 2010

Project

The N57 road forms the connection between the Motorway A15 near the city of Brielle and the Motorway A58 near the city of Middelburg and will be upgraded from the existing regional road standard to motorway standards. Since the road now accommodates both normal and slow traffic and crosses several villages, it will be upgraded not only to improve mobility but also to improve road safety and the living conditions along the road, i.e. minimise the nuisance due to the road.

The N57 follows a North-south line across the island of Walcheren and crosses several other roads as well as the “Canal through Walcheren”. For this crossing, an Aqueduct / tunnel will be realised. The total length of the structure, including access ramps will measure some 850 m while the covered part of the aqueduct will have a length of 155 m. The tunnel will accommodate 2 x 2 traffic lanes with an internal size of 9.2 m for each bore. The structure will be partly constructed in-situ and partly as an immersed tunnel.

The project has been realised under a Design & Built contract. For the first phase, TEC partner Royal Haskoning provided the tender design. Following contract award to the consortium, the detailed design was further developed.

The design services also included the horizontal and vertical alignment, the design of the earthworks and the design of all engineering structures.

Figure: The immersion process in progress

Figure: The element in place

TEC’s scope of work

- Tender design
- Detailed design

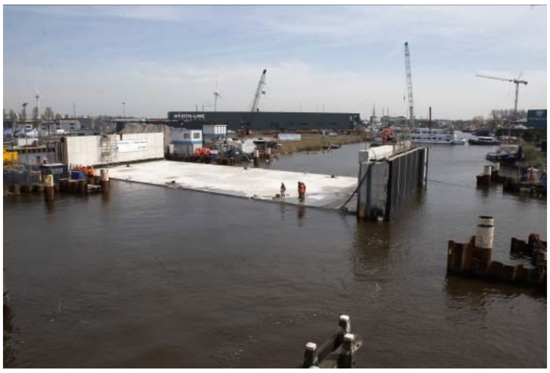
TEC Tunnel Engineering Consultants

N31 Aquaduct Harlingen, the Netherlands

Project

The new alignment of the N31 provincial road at Harlingen, Friesland, goes around the city centre of Harlingen and crosses the Harinxma canal, parallel to the old bridge in the existing N31 road. Due to the number of recreational (sailing) vessels passing the existing moveable bridge in the N31 being the cause of usual traffic delay, the new crossing has been designed as an aqueduct under the canal.

The cross section of the aqueduct comprises two motorway tubes with 2 lanes each, with a low internal wall with columns in between. The aqueduct is suited only for motorway traffic.



TEC's scope of work

Civil, structural and marine works:

- Transport and immersion engineering and work preparations of transport configuration, provisions and equipment for float up, transport, immersion, installation and sand flow of the aqueduct element
- Ballast plan, ballast capacity, jacking plan and sand flow calculations
- Geo-hydrological advisory of canal bottom and shore protection
- Construction methods, construction time schedules and transport and immersion time schedules
- Operational management and command of all preparations phases and transport and Immersion operations
- Advisory and provision of working/construction method and guidelines for post-immersion finishing works such as ballast exchange (in co-operation with the client)
- Advisory and supervision upon construction (in co-operation with the client)

SPECIALIST MECHANICAL & ELECTRICAL SERVICES/SAFETY STRATEGIES

General

In addition to the design and consultancy services related to tunnel technical installations that make part of the various civil works assignments by TEC and its partners, also specialist (stand-alone) M&E Services have been provided. The following projects are described hereafter.

- Traffic Control Centre for the southern part of The Netherlands
- Traffic Control Centre for the eastern part of The Netherlands
- Dordrecht region tunnel and bridge installation renovation
- Botlek tunnel renovation, the Netherlands
- North-South Metro Line Amsterdam - The Netherlands [1994-2017]
- Sharq Crossing Doha – Qatar [2013-2014]
- Increasing capacity Coentunnel route Amsterdam – The Netherlands [2011-2012]
- Road-Rail Tunnel Nijverdal – The Netherlands [2012-2013]
- Sluiskil Tunnel Terneuzen - The Netherlands [2009-2015]
- Westerscheldetunnel System Design and Renovation 2017 – The Netherlands [2012]
- Fehmarnbelt immersed tunnel - Denmark-Germany [2009-2012]
- Markt-Maas Project Maastricht – The Netherlands [2004-2006]
- Thomassen Tunnel Rotterdam - The Netherlands [1998-2004]
- Mexico City New International Airport - Mexico [2015-2016]
- ShenZhong Link – China [2015-2016]
- Piet Heintunnel- fire resistance
- Amsterdam Tunnel Renovation Program
- Renovation / upgrading 1st Heinenoord Tunnel, the Netherlands

Projects of which M&E Services was a significant part but that were described earlier in this Experience Record are:

- Noordtunnel, the Netherlands
- Wijkertunnel, the Netherlands
- Daugava tunnel, Riga, Latvia
- New Tyne Crossing, United Kingkom
- Busan – Geoje Link, South Korea
- Oosterweel tunnel, Belgium
- Santos Crossing, Brazil
- South taxiway tunnel, The Netherlands
- Amsterdam Schiphol Airport Freight traffic tunnel, the Netherlands
- Aqueduct Gaag, the Netherlands

Traffic Control Centre for southern part of The Netherlands

Project

The Traffic Control Centre for the southern part of The Netherlands is located in Geldrop. This centre processes data received from the roadside installations in the provinces of Noord-Brabant and Limburg. These installations are linked to the traffic control centre by telemetry systems. The traffic control centre is used by the Ministry of Traffic and Public Works to inform, guide and direct road users.

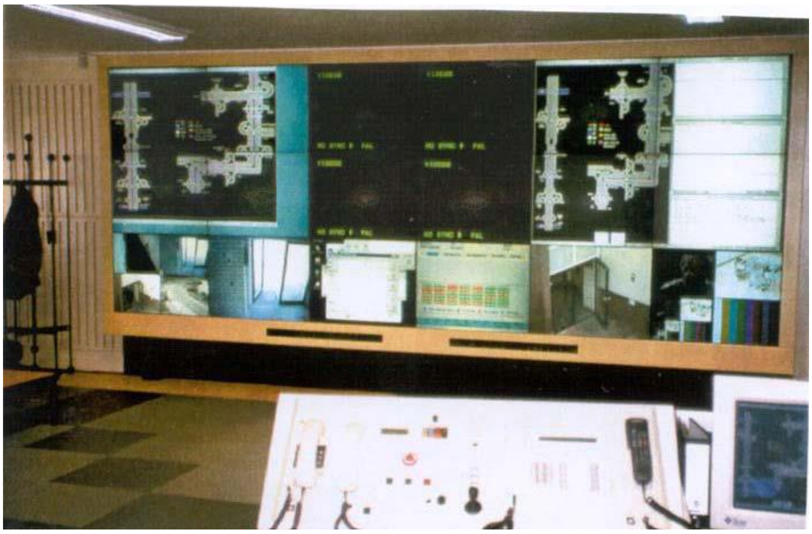


Figure: Plan of the Traffic Control Centre

TEC's scope of work

The work consisted of:

- Basic design
- Final design
- Development of tender documents
- Supervision, and
- Project management

Traffic Control Centre for eastern part of The Netherlands

Project

The Traffic Control Centre for the eastern part of The Netherlands is located in Wolfheze. This centre processes data received from the roadside installations in the provinces of Gelderland, Drenthe, Groningen and Friesland. These installations are linked to the traffic control centre by telemetry systems. The traffic control centre is used by the Ministry of Traffic and Public Works to inform, guide and direct road users.

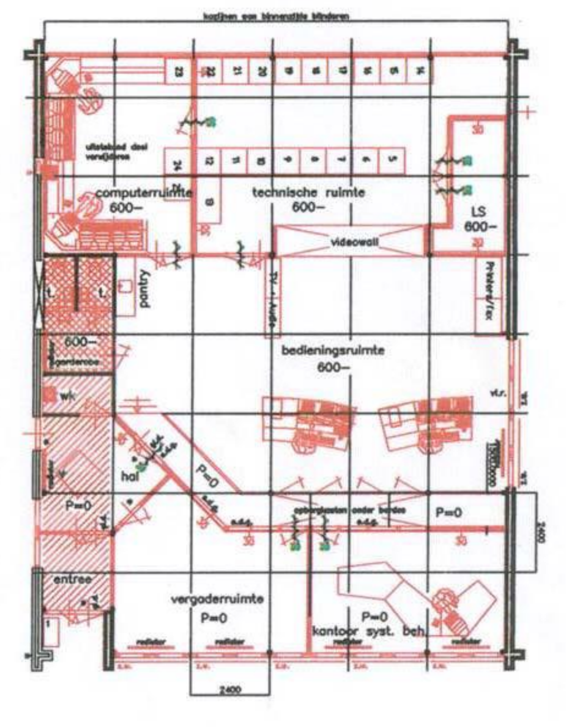


Figure: Plan of the Traffic Control Centre

TEC's scope of work

The work consisted of:

- Basic design
- Final design
- Development of tender documents
- Supervision, and
- Project management

Dordrecht region tunnel & bridge installations renovation

Project
The technical installations of the traffic control systems in the Dordrecht region were outdated and needed to be replaced. Due to the fact that new and improved technology became available as well as new legislations for tunnel installations, the Tunnel Engineering Department of the Ministry of Transport and Public Works commissioned TEC to provide their services to renovate the control systems for the “Drecht” and “Noord” tunnel, as well as the bridge over the river “Noord”, the “Wantij” bridge and the “Papendrechtse” bridge.

The renovation of the installation systems and control units for the three motorway bridges included the energy supply (opening and closing), traffic lights for ships, traffic lights for cars, traffic barriers, hydraulic drive, emergency motor (in case the main motor breaks down), CCTV-installations (cameras), noise barrier installations, video screens and building installations (heating, ventilation, sanitary installations).
The renovation of the installation systems and control units for the two motorway tunnels included energy supply, ventilation, lighting, emergency buttons (to close off the tunnel), UPS (uninterruptible power supply), drainage, traffic installations (cameras, traffic sensory systems), communication (phones, speakers) and fire fighting installations.

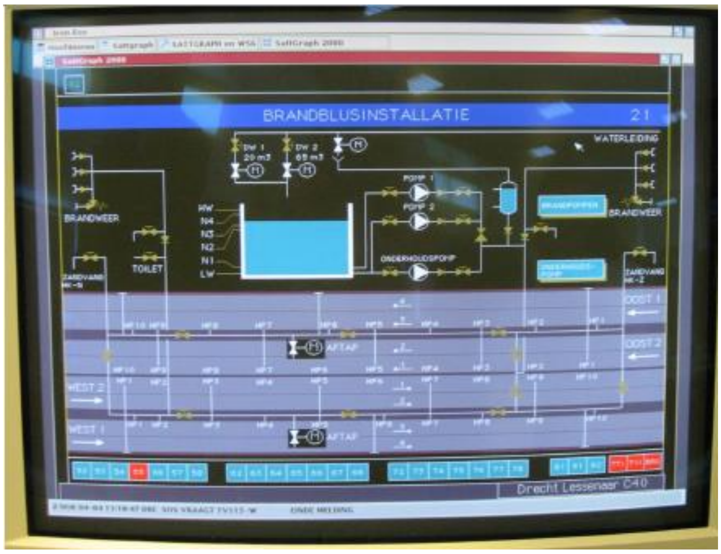


Figure: Installations

TEC’s scope of work
- To prepare a conceptual design, a final design and tender documents.
- Control of detailed engineering and construction of the installations.
- Responsible for construction supervision management on site.

Botlek tunnel renovation, the Netherlands

Project

The project relates to the renovation of the emergency power installations and Speed Discrimination System of the Botlek tunnel.

The mechanical and electrical installations that required renovation consisted of:

- Energy power systems
- Distribution systems
- UPS-system
- Speed Discrimination System
- Plant control and control systems

Figure:

TEC's scope of work

- To prepare a conceptual design, final design and tender documents.
- Control of detailed engineering and construction of the installations.
- Responsible for construction supervision management on site.

North-South Metro Line Amsterdam - The Netherlands [1994-2017]

Project

To relieve the existing public transport system (bus, tram, metro and ferry lines) in and around Amsterdam, the existing metro system will be complemented by an additional 5th line, the North-South line. The new line is expected to provide transport for approximately 200,000 people a day. The 1st part of the line extends from the A10 ring road in Amsterdam North to the A10 ring road in Amsterdam South and has a length of 9.5 km.

The line includes sections on an embankment, in open ramps, through in-situ, immersed and bored tunnels as well as through pneumatic caissons. The stations are at surface and at various depths, up to 30 m, under the streets of the ancient Amsterdam city center and extremely close to historic buildings.

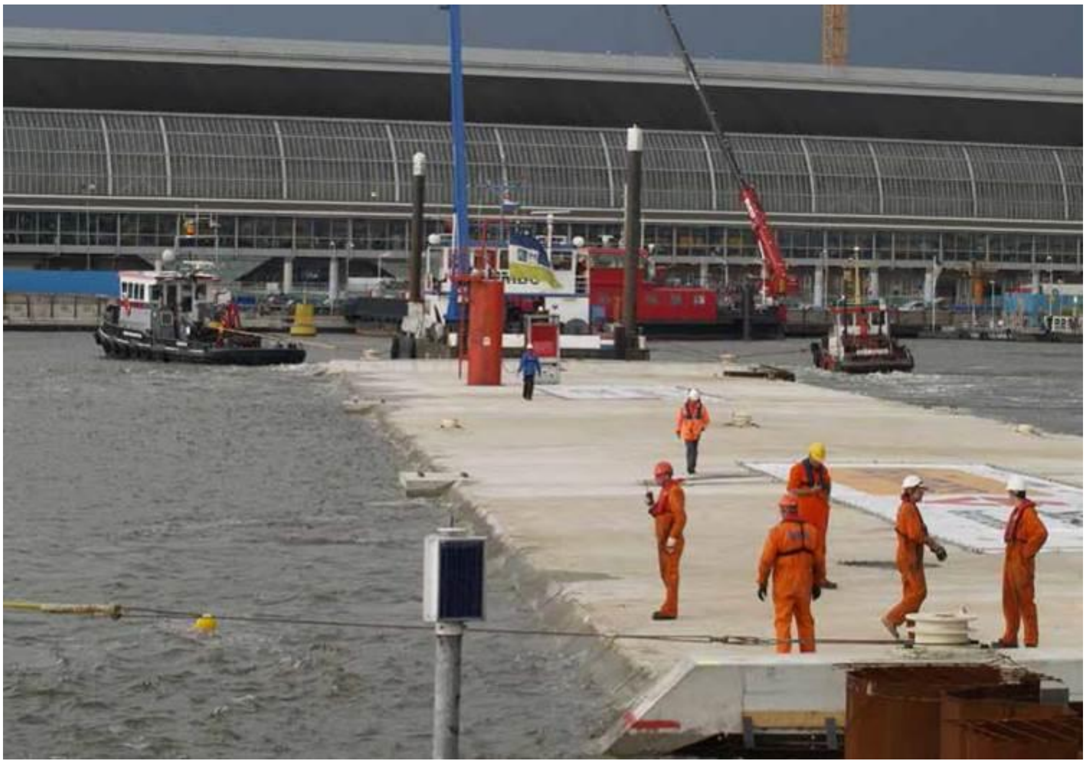


Figure transportation and immersion of tunnelelement.

TEC's scope of work

Safety Concept

An integrated safety approach has been developed by the TEC parent companies for the new underground North/South metro line based on the "Safe Haven" concept. As legislation in the Netherlands did not provide a safety framework for underground structures, a project specific concept has been developed.

Evacuation and fire-safety design of the underground mass transit system (with bored and immersed tunnels, underground stations, rolling stock) are the main safety topics. A functional fire safety approach (FSE) has been followed. The leading principle of the safety concept is that all the measures will be taken to ensure that in case of emergency the trains will reach the stations. The tunnels are situated at such depth that emergency crews cannot be on hand immediately

in case of an incident. The passengers should therefore in all situations be transported to the stations. These stations are the Safe Havens. A rapid and safe evacuation from the stations is of utmost importance for the total safety concept.
The depth of the platforms and spatial constraints required a solution in which safe evacuation will be supported by escalators and an emergency ventilation system. The stations are furthermore equipped with emergency power supplies, detection systems, smoke and heat extraction systems, fire proofing etc. to prevent or control incidents.

The TEC parent companies were responsible for the design of the Integral Safety Concept and all the safety assessments like: Fire safety analyses (FSE), Quantitative risk analyses, HAZOP, Hazard Logs, Safety Cases, evacuation simulations (3D), Smoke extraction and CFD modelling, program of safety requirements. The fire load assessment and structural integrity requirements were also part of the works performed. This concept has been developed in dialogue with both the legislation authorities and rescue services.

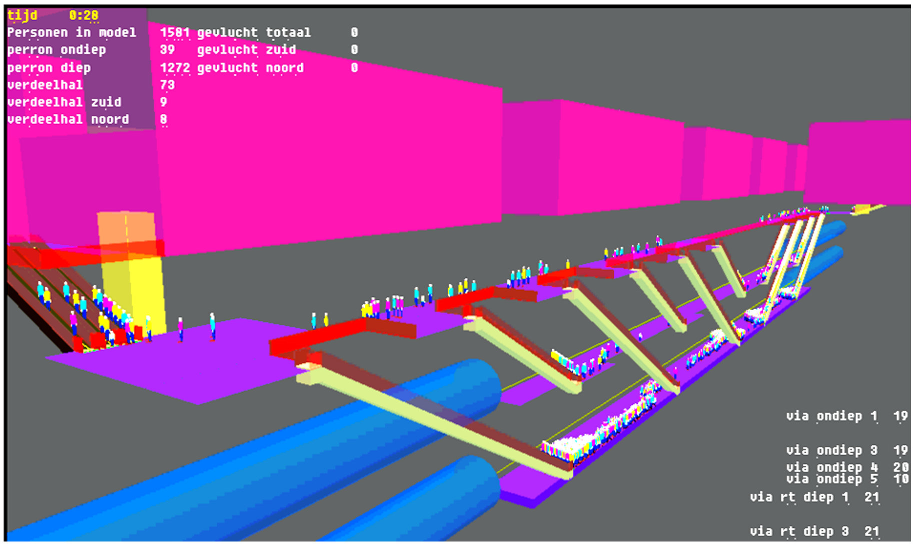


Figure general safety concept for tunnels and all underground stations, including many evacuation and transfer modelling and CFD simulations.

Figure CFD-modelling of Central Station.

<u>Systems</u>

Functional and technical specifications for all the mechanical and electrical systems (MEP-systems) of the metro system are developed by TEC, taking into account the specific (safety) requirements and constraints of the underground structures.

Parts of the design-services are the following subsystems:

- Escalators and elevators;
- Smoke exhaust systems (emergency ventilation);
- Ventilation (HVAC);
- Electrical Power supply (trains and systems);
- Lighting systems;
- CCTV- and communication systems;
- Emergency stations;
- Pumping and drainage systems;
- Detection systems.

All these systems are designed in compliance with the reliability and safety requirements as part of the integral RAMS and Life Cycle Cost (LCC) assessments.

Sharq Crossing Doha – Qatar [2013-2014]

Project

The new approximately 12 km bridge-tunnel connection Sharq Crossing is a vital part of the Greater Doha Transportation Master Plan. In recent years the city of Doha has seen considerable increase in population, car ownership and new city districts. It is forecast that the area will experience serious traffic problems in the near future. This Bridge-Tunnel Link is crossing the Doha Bay.

The Link consists of three major bridges, two immersed tunnels, a marine interchange for the connection of one of the bridges to the two tunnels, two marine islands for the connection of the tunnels to the bridges and three land tunnels at the landing points.

The Sharq Crossing contains two immersed tunnels (2*3 lane and 2*2 lane with escape lane) with a length of approx. 2.800m each. The 2x3 lane tunnel has a width of 45.5m and a height of 11.1m. The 2x2 lane tunnel has a width of 34.2m and a height of 11.1m. Each immersed tunnel is built up out of tunnel elements of 150m. The marine interchange is a subsea traffic junction connecting one of the bridges to the immersed tunnels and has an overall length of approx. 600 m and a width of around 100m. The land tunnels are connecting the bridges to the shore and linking the crossing into the local road network they have lengths varying from 1.000m to 1.500m.

TEC's scope of work

TEC prepared the validated concept Design of the 2 immersed tunnels of 3.1 and 2.8 km and the 3 cut-and-cover tunnels with a length of approximately 950-1250 m connecting the bridges to the main land and the Marine Interchange, connecting the 2 immersed tunnels and one of the bridges.

The assignment also included the design of mechanical, electrical and plumbing (MEP) systems, the Integral Safety Concept, including ventilation.

TEC worked together with HBI Haerter Ltd. (Zurich, Switzerland) for tunnel safety and tunnel ventilation.

The project included 5 phases. The recent sub consultancy agreement covered the first project phase: Concept Design Validation. TEC has executed the first phase in 5 months time, which started in September 2013 and was completed by January 2014.

Figure interior of the tunnel.

Figure Tunnel safety strategy and concept.

Tunnel Engineering Consultants

Increasing capacity Coentunnel route Amsterdam – The Netherlands [2011-2012]

Project

Over one hundred thousand cars were daily using the 1st Coen tunnel, which is much more than this motorway section can handle. In order to regenerate the traffic flow, the Dutch Public Works decided to expand this motor way section by the realization of the 2nd Coen tunnel and the renovation of the existing tunnel.
In order to connect the tunnels to the A8 and A10 motorways, various connecting roads had to be realized as well. Rather than the actual technique, the challenge of the project is based on the requirement that the link must be fully operational during construction of the new tunnel, the rehabilitation of the old tunnel and the integration into the new expanded road network. Moreover this tunnel was the first tunnel in the Netherlands that to comply with the new Dutch Tunnel Standard including very stringent requirements in terms of verification and validation.

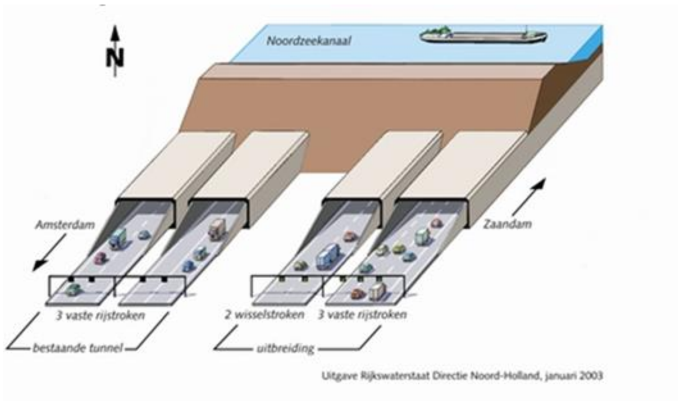


Figure overview first and second Coentunnel.

TEC's scope of work

Through parent company Royal HaskoningDHV, TEC provided various design services:

1. Final Design for the traffic and tunnel systems (TTS) to realize an increased capacity for the Coen Tunnel route based on the System Design:
   - Design subsystems for TTS system, such as communication systems, control systems, power supplies, lighting and ventilation systems, building services, fire extinguishing, traffic and drainage systems, etc;
   - Technical design in text and/or single-core wiring diagrams and/or I/O lists, light calculations, cable calculations, power balance/energy matrix, capacity of pumping systems, water hammer analysis, etc;
   - Specification of procedures for verifying the requirements associated with the system;
   - Coordination interfaces and defining interface requirements;
   - Coordination space aspects and recesses for the traffic and tunnel systems;
   - Reliability, Availability, Maintainability, Safety, Health and Environmental analyses associated with the system.

2. System Design for the traffic and tunnel technical systems (TTS) to realize an increased capacity for the Coen Tunnel route based on requirements specified by the Ministry of Public Works:

- Preparation of integrated design at level 0 (highest level of the System Engineering methodology) for the TTS system, applying the methodology of system engineering;
- Preparation safety and tunnel scenarios (flow of events in time), including what-if analyses (analysis and evaluation of the effects of a failure of one or more of the related systems during each scenario step), in order to discriminate the critical events;
- Preparation system scenarios on the basis of these safety and tunnel scenarios (response of the technical system) in which the integrated operation of the subsystems of the TTS system is shown;
- Allocation of the requirements to the subsystems for the TTS system, such as communication systems, control systems, power supplies, lighting and ventilation systems, etc;
- Identification of system interfaces;
- Specification of the procedures for verifying the requirements associated with the system.

3. Master test plan traffic and tunnel systems

To full fill the operational requirements and secure the safety aspects, the traffic and tunnel systems (TTS) will undergo a strict verification and validation process. This set of procedures will assure the quality and cohesion of the delivered (sub)systems and the integrated operation of the system.
The Master Test Plan' (MTP) describes these processes at a strategic and tactical level, documents the verifications to be performed, at what level and who is responsible. In respect to the System Engineering methodology, the MTP is the leading document in the verification and validation.

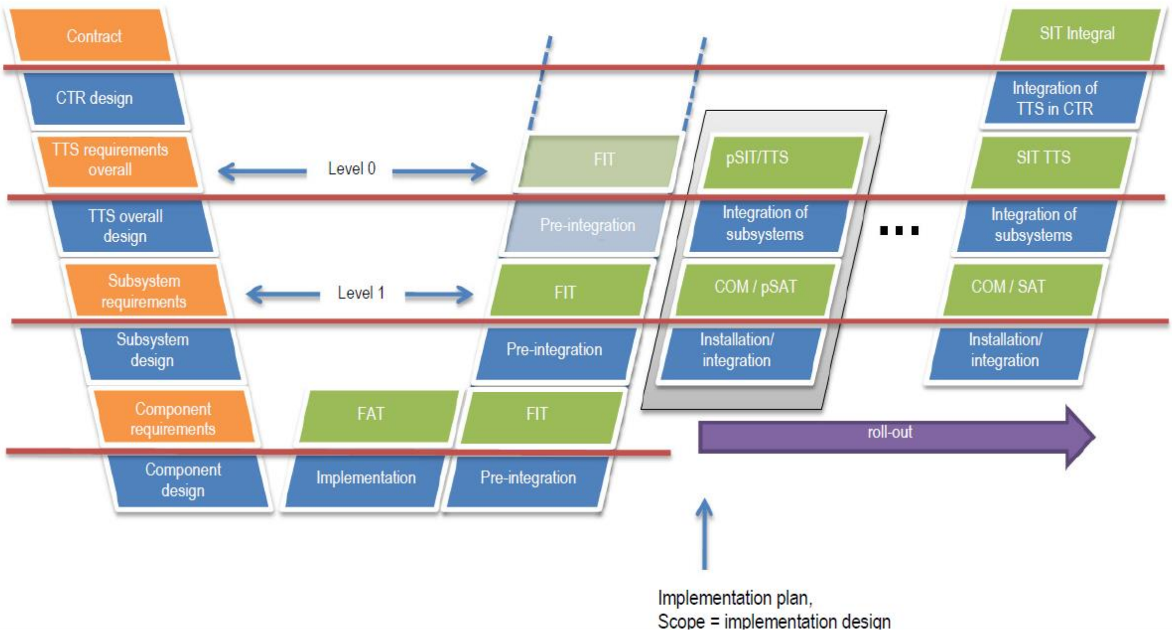


Figure V-model design traffic and tunnel systems 2nd Coentunnel.

Road-Rail Tunnel Nijverdal – The Netherlands [2012-2013]

Project

The center of Nijverdal is one of the last city centers in the Netherlands that is split in two by a national highway/railway. This obviously has a detrimental effect on the livability, traffic flow and traffic safety in the Nijverdal center. To improve this situation, the city council, together with the Dutch Ministry of Transport and Public Works have initiated the "Combiplan" project that aims at abandoning the through traffic from crossing the city center.

Figure overview road- and railtunnel.

The Nijverdal Combiplan project includes a 400 m long tunnel section, with an open-tunnel section and approach ramps on both ends. The tunnel will accommodate 2 x 2 traffic lanes, each of which will be in a separate tube. The tunnel will also accommodate the double track railway line.
The entire project also includes all associated works on the surface and is realized under Design & Built. The contractor for the project invited TEC to provide the structural design for the road and railway tunnel. TEC has undertaken this assignment using System Engineering methodology.

TEC's scope of work

Through parent company Royal HaskoningDHV, TEC was responsible for the integrated M&E design for the road tunnel.
The services comprise:

- Conceptual, preliminary and final design Tunnel Technical Installations;
- Development scenario-analyses;
- Technical management;
- Preparation of the System Development Plan;
- Reliability, availability, maintainability and safety analyses, including Fault Tree Analyses and Failure Mode and Effects Analysis;
- Support with methodology of System Engineering;
- Support with development of Software.

Sluiskil Tunnel Terneuzen - The Netherlands [2009-2015]

Project

The Sluiskiltunnel is built alongside the present bridge over the Channel from Gent to Terneuzen. It provides a better connection between the harbours of Antwerp and Rotterdam. As this Channel is sailed by many Ocean Bulk Carriers the bridge was opened for 5 hours per day. A tunnel provides a permanent available connection for the increasing (cargo) traffic. The Sluiskiltunnel is a 1600 m twin bored tunnel with a diameter of approximately 11 m. On both sides of the Gent-Terneuzen Channel ramps of about 300 m are built. The tunnel is built in soft subsoil in a polder area.

Figure entrance of the bored tunnel.

TEC's scope of work

Through parent company Witteveen+Bos, TEC was the consultant to the Owner of the project:
The services comprise:

- Preparation reference design (civil and M&E) and tender documentation;
- Checking detailed design and construction supervision.

Westerscheldetunnel System Design and Renovation 2017 – The Netherlands [2012]

Project

The project contains maintenance and renovation of the Westerschelde Complex during the period 2013-2033. The new maintenance contract will be set up through a tender. The renovation of the tunnel will take place in 2017 and concerns replacement of several tunnel technical installations. The maintenance will be carried out, causing no traffic jams for the current traffic flow.
Apart from design and project management, support was given for the tendering procedure (amongst others defining selection and allocation criteria).

Figure southern entrance of the Westerschelde tunnel.

TEC's scope of work

Through parent company Royal HaskoningDHV, TEC provided various design services, including setting up the System Design and the Tunnel Technical Installations. The System Design was carried out for the benefit of maintenance and renovation of the Westerschelde Complex, based on the (historical) data provided by the client and demand specifications of Rijkswaterstaat (part of the Dutch Ministry of Infrastructure and the Environment). The work was carried out following the Systems Engineering model.
For the Renovation part a questionnaire has also been drawn up, which is an integral part of the Maintenance Contract. In addition to the design work carried out and the associated project management, support has also been given to the procurement process (including market consultation, selection requirements, award criteria and procurement).

Figure view of western tube of the Westerschelde tunnel.

Fehmarnbelt immersed tunnel - Denmark-Germany [2009-2012]

Project

Realizing the last missing link between the mainland of Europe and Scandinavia, an immersed tunnel between Denmark and Germany. From 2028 the distance between the two countries will be reduced to just 12 minutes. With its 19 km, the Fehmarnbelt tunnel will be the longest combined road and tunnel in the world. The tunnel consists of a 2x2 lane motorway with emergency lanes, an escape- and service gallery and 2 single track train tubes.
Safety aspects of such a tunnel request an enlightened approach to safety. The combination of car- and rail traffic in one tube diameter has the advantage that in case of an emergency, several non-incident tubes can act as safe escape. The safety requirements have mayor effect on the design of the tunnel technical installations, which have to comply with European laws and regulations.

Figure location of the new Fehmarnbelt tunnel.

TEC's scope of work

The project was carried out by the joint venture RAT, consisting of Ramboll, Arup and Tunnel Engineering Consultants. TEC was responsible for the conceptual design of the tunnel technical installations (E&M), the integration of systems in the civil construction, costs, implementation planning and the operation and maintenance plan.
In addition, TEC performed life-cycle calculations for the annual maintenance costs over the complete lifecycle of the tunnel.

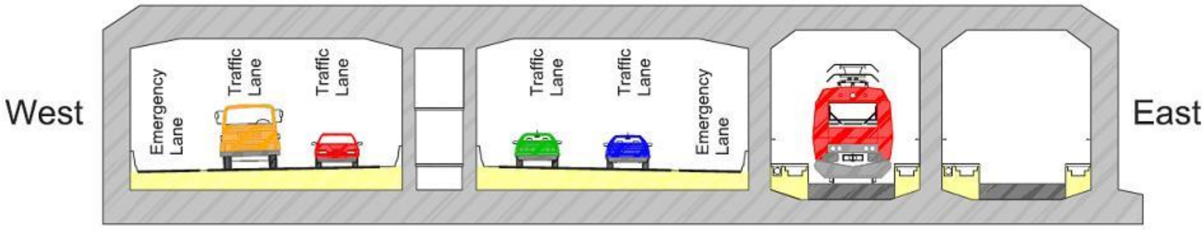


Figure cross section of the Fehmarnbelt tunnel.

Markt-Maas Project Maastricht – The Netherlands [2004-2006]

Project

The city of Maastricht has initiated the redevelopment of the inner-urban area between the market and the western bank of the river the Maas. The development includes the realization of a tunnel, a four-storied underground car parking station, with a shopping centre and municipal offices above it. The cut-and-cover tunnel has a length of 400m, which includes separate entry and exit lanes which amounts to 700 metres of which 400 meters is closed.

Figure: Junction on the Southern side inside the tunnel tube.

TEC's scope of work

Through parent company Royal HaskoningDHV, TEC was invited to advice on the maintenance of the E&M installations of the tunnel. In cooperation with the Maastricht municipality management department, TEC provided consultancy services regarding the management of all technical installations in the tunnel as well as those used for tunnel surveillance. The following installations are maintained: fire ventilation, tunnel lighting, C2000 system, PA system, fire alarm installation, CCTV installation, controls, standstill detection, escape route marking and escape route lighting.

The services comprise:

- Supervision of the maintenance contract with the contractor;
- Planning corrective maintenance;
- Inspection and evaluation of the work by the contractor;
- Initiation of supplementary work related to improvement of the installation and changes in the use of the tunnel;
- Coordination of work that must be implemented within the interface between the car park and the super structure.

Thomassen Tunnel Rotterdam - The Netherlands [1998-2004]

Project

The extension of the A15 motorway to the so-called Maasvlakte crosses the Caland Canal. For this crossing a tunnel has been constructed with a total length of 1500 m accommodating 2x3 road lanes and a service/escape duct. The tunnel is suited for transport of dangerous goods (category I).
The enclosed part of the tunnel is 1100 m. The section below the canal will be constructed with the immersed tunnel technique, with six elements of 115 m.

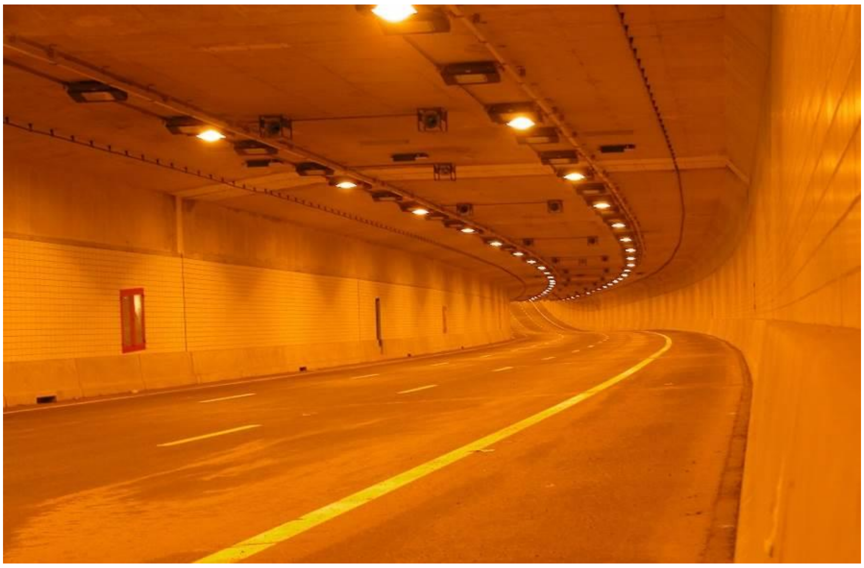


Figure view of tunnel tube with 3 lanes of the Thomassen tunnel.

TEC's scope of work

TEC was responsible for the integrated E&M design for the complete tunnel.

The services comprise:

- Functional and design requirements;
- Preliminary design and final design, including calculations, drawings and schemes;
- Risk analyses;
- Tender documents;
- Cost estimates;
- Review of contractors detailed design;
- Monitoring and construction supervision.

Mexico City New International Airport - Mexico [2015-2016]

Project

The new airport will replace the Mexico City International Airport, which is at full capacity. The new airport will have three runways to start and will be expandable to up to six runways. With three runways in simultaneous use the airport will be able to serve up to 50 million passengers per year. The site for the new airport is located at the east of Mexico City. It is positioned within an area that was formally covered by Lake Texcoco; the lake has now dried up but the resulting ground and groundwater conditions are challenging.

The design of the tunnels is challenging due to the soft soil conditions, heavy airplane loads crossing the tunnels and severe seismic conditions. The safety concept and MEP design was developed by TEC.

Figure overview terminals new international airport.

TEC's scope of work

TEC is a subconsultant for the NAICM project and is responsible for the design of the tunnels and the installations during the conceptual and final design phase of the project. Support and checking is provided in the detailed design phase. The tunnels in the project are constructed with the cut & cover method.

The services comprise the following tunnels:

- Two Ground Service Equipment (GSE) tunnels with a length of 1300m. The GSE tunnels will be used by airport busses, catering trucks and tow-vehicles;
- Two airport utility tunnels parallel to the GSE tunnels;
- A public road tunnel used by supply trucks, passenger cars and busses carrying employees to the Support Area;
- A third GSE tunnel to connect the Maintenance Area with the Airport Support Area and Cargo.

ShenZhong Link – China [2015-2016]

Project

The People's Government of the Guangdong Province plans to build a sea-crossing link between Shenzhen and Shongshan. This Shen-Zhong Link is located about 30 km to the south of the Humen Bridge in Guangzhou and about 38 km to the north of the Hong Kong-Zhuhai-Macao Bridge (HZMB) Link.

The new link will shorten the commuting distance of two economic circles sitting on the east and west shores of the Pearl River. The link is not only a corridor for Shenzhen and Zhongshan, but is also for strategic importance to the Nansha, Qianhai, Cuiheng and Hengqin areas of the city of Guangzhou, Shenzhen, Zhongshan and Zhuhai respectively. Upon completion of the link, the travel time from Shenzhen to Zhongshan will be significantly reduced, from more than two hours to twenty minutes in clear traffic.

The connection has a length of 24 km, has 4 lanes in both directions and starts at a new artificial island south of the Shenzhen airport where the link is connected with the Guangzhou-Shenzhen Riverside Expressway. From there it passes underneath the Dachan waterway, the Airport Secondary Fairway and the Fanshi Waterway with a tunnel. At the West Artificial Island the tunnel switches to a bridge crossing the Lingdin West Fairway and the Hengmen East Waterway with a suspension bridge, approach bridges and a cable stayed bridge. At the Hengmen Interchange the link is connected with the Zhongshan-Kaiping Highway.

The immersed tunnel possesses 2 traffic tubes and a central gallery with a total width of 46 m and a length of 5.25 km. For the deep sections, reaching water depths of 35 m, full steel sandwich elements turned out to be most economical. For the less deep and wider sections single shell elements were proposed. As this will be the first full steel tunnel in China the cross-sections were developed in detail.

Figure overview artificial island and the suspension bridge.

TEC's scope of work

TEC, in combination with the Guangdong Highway Reconnaissance Planning Design Institute and Information Based Architecture, prepared a set of design documents covering all aspects of the tunnels, islands and bridges.

The TEC, GDDI and IBA joint venture ended second in the competition. The client amongst others valued the technical depth of the study and the practical knowledge and experience brought in from other large tunnelling projects.

The TEC scope of services covered the integral design of the immersed tunnel and the artificial islands. The following items were prepared by TEC and were included in the competition documents:

- Architectural design and landscaping;
- Structural safety and foundation design;
- Mechanical and electrical installations;
- Life safety;
- Construction methodology and schedule;
- Construction cost estimate.

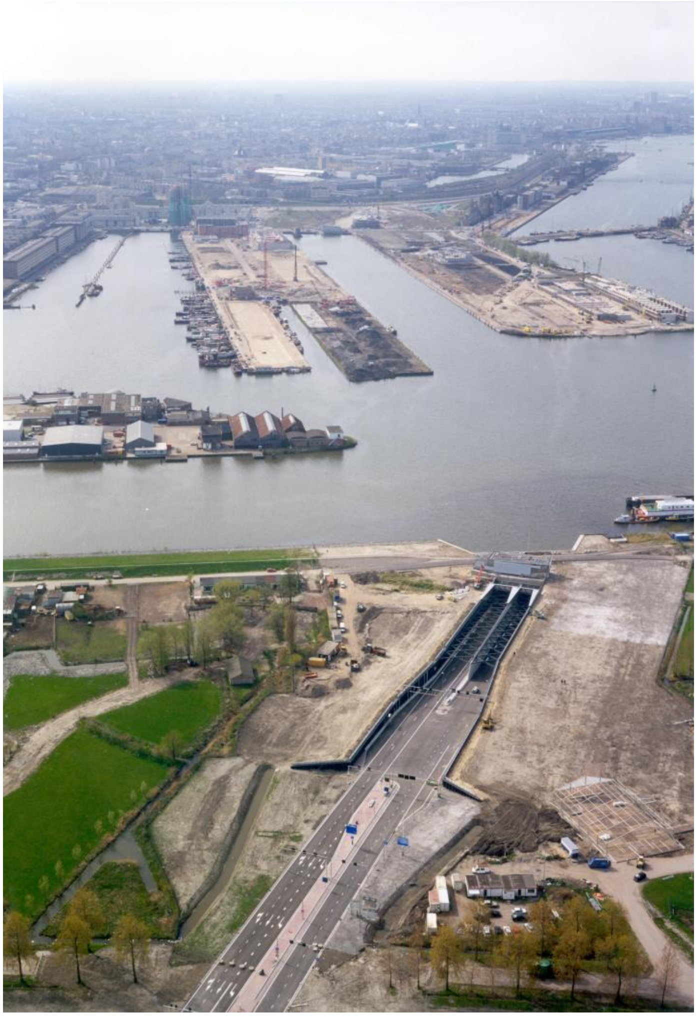
Figure overview Shen Zhong Link.

Piet Heintunnel- investigation of the fire resistance

Project description

The Piet Heintunnel is part of the road and public transport connection between the Amsterdam Central Station and the eastern motorway and new suburb IJ-burg. This project was realized in the nineties of the previous century within the framework of the accessibility of the city of Amsterdam. The tunnel has a total length of approx. 1950 m and contains 2 traffic tubes with 2 lanes, and escape cell and a tube with two tram tracks.

Under the new regulations "Building Act 2003" and the more stringent requirement for the fire load, TEC was requested by the City of Amsterdam to advice on the fire resistance of the Piet Hein tunnel



TEC's scope of work

TEC has conducted an investigation into the fire resistance of the main structural components of the Piet Heintunnel. Within this study the closed tunnel section, including the immersed tunnel and the ramps were considered. Advice has been provided regarded the safety, integrity and recoverability of the damage by fire of the main structural components.

Amsterdam Tunnel Renovation Program

Project

Early 2019, the municipality of Amsterdam launched a tender for a framework agreement for (technical) consultancy services within the framework of efficient future operation, management and maintenance of the municipality road tunnel system, covered under the Amsterdam Road Tunnels Program.

This program involves the renovation / upgrading of three tunnels and the development of a new traffic control centre. The main Municipality goals of the program were to have full compliance of the tunnels with the current legislation and codes and to create a solid basis in order to enable efficient uniform operation, management and maintenance strategy of the integrated road tunnel system as a strategic asset to the Municipality of Amsterdam.

The current program involves the following items:

- The renovation and upgrading of the Piet Hein tunnel; the tunnel was realized in the nineties under more relaxed tunnel safety requirements and requires an upgrade to meet current tunnel safety legislation. The tunnel is approx. 1.9km long including immersed tunnel of 1280m; the tunnel has two traffic tubes accommodating 2x2 road lanes, a central gallery for evacuation and services and a separate tube with two tracks for light rail.
- Upgrading the tunnel installations and systems in the Amsterdam Arena tunnel; the tunnel was constructed in the mid-nineties as part of the Amsterdam Arena and under passing the Ajax football stadium / parking. The tunnel is approx. 300m long.
- Detailed assessment of the performance of the fire proofing material of the Michiel de Ruijter tunnel; the tunnel was opened in 2015 and part of the main public transport hub around Amsterdam Central Station. Within the framework of the new legislation regarding tunnel safety, the fire proofing material in the tunnel had to be re-assessed and tested in detail.
- Assessment of upgrading of the existing Traffic Control Centre Amsterdam, managing the operation of all Amsterdam tunnels and the investigation and development of a completely new Traffic Control Centre at a new location.

Photo Municipality of Amsterdam

TEC's scope of work

TEC provides technical consultancy for the Amsterdam Tunnel Program participating with experts in integrated Owners' project teams and by preparing separate design studies and services. Services completed or currently on going:

For the upgrade of the Piet Hein Tunnel:

- Technical MEP related designs
- Detailed assessment of fire resistance of civil structures subjected to fire loads under new tunnel safety legislation
- Development of an advanced BIM / Digital Tunnel Twin to realize a virtual environment for testing, education and future operation of the tunnel (in corporation with Infranea)

TEC experts are currently working in an integrated team of the Owner and the Contractor that are preparing and executing the renovation works (NEC4 / Alliance).

For the upgrade of the Amsterdam Arena Tunnel:

- Technical MEP related designs meeting current legislation
- Development of an advanced 3D BIM / Digital Tunnel Twin to realize a virtual environment for testing, education and future operation of the tunnel (in corporation with Infranea).

TEC experts are working in an integrated team of the Owner in the design phase.

For the Michiel de Ruyter Tunnel:

- Code compliance fire resistance of tunnel structures (fire resistance studies and tests).

For the Traffic Control Centre:

- Preparation Operational Concept Design / Functional and technical requirements
- Employers' requirements / space requirements Control Centre
- Assisting in development of Proof of Concept

Renovation / upgrading 1st Heinenoord Tunnel, the Netherlands

Project

The 1st Heinenoord tunnel is part of the National Motorway Network and located in the A29 Motorway, close to Rotterdam. The tunnel was built in the late sixties and has a length of 1064 m; the closed section is approx. 614m long of which 571m is immersed (5 tunnel elements). The tunnel was originally accommodated with 2 road lane and a slow traffic lane. In the nineties a second (bored) tunnel was constructed which now carries the slow traffic. The old tunnel now accommodates 2x3 road lanes in two traffic tubes (but is missing a central gallery).

The old Heinenoord tunnel is currently being prepared for a substantial renovation and upgrading in order to meet current legislation. Next to upgrading systems and installations, a central gallery will be realized for escape and installations. It will be the first tunnel in a substantial renovation program of tunnels in the national road network in the province of South Holland. The renovation works for the 1st Heinenoord tunnel are scheduled for 2021-2023.
One of the challenges of the project is that the local road network is very congested and deviation routes are not available. One of the focus areas of the project is the limitation of disruption to the traffic and to keep the tunnel as much as possible available. Long closures of the tunnel are therefore not allowed, which has a significant impact on the planning of the renovation works:

- 2 x 2 weeks full closure of the tunnel (to construct central gallery and transfer from existing systems to new systems)
- 30 weekend single tube closures and 30-night single tube closures
- 2 weekends full closure
- Public transport (buses) will use the adjacent slow traffic tunnel during the closures

Scope of work

TEC is involved in this pilot renovation project as the Client Consultant and working in an integrated Project Organization with the Owner:

- Technical MEP related designs
  - All tunnel installations and systems
  - Standardization strategies for command, control, communication and safety / security systems

- Technical Civil Designs
  - Implementation of additional inner wall to create central gallery (structural and construction staging)
  - Inspection and assessment of joints
  - New Code compliance (EU-code especially regarding shear capacity)
  - Small items (fire proofing materials, barriers etc)

- Interface and stakeholder management
  - Communication with internal and external stakeholders.
  - Identification of requests / requirements of internal stakeholders (Public Works departments including operators) and external stakeholders (municipalities, water boards etc.)
  - Evaluation of all requests and translate accepted ones to smart technical and contract requirements
  - Manage interfaces between various inter-related activities and various disciplines and translate to smart technical and contract requirements
  - Development of SE-based system (Relatics) in which all requirements are listed and managed