Tunnels & Tunnelling
Experience Record

Bored tunnels
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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

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
- Safety aspects
  - Safety analysis
  - Operational procedures
  - QRA and Scenario Analysis
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 Heineenoord 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
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](image)

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
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) Heinenoord tunnel, 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.
**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
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 Zhuai 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*
**TEC's scope of work**

TEC has carried out the entire and independent parallel concept design for different alignments of Shenzhen 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)/Samsung (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.