Tunnels & Tunnelling
Experience Record
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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 live 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
  - Engineering
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
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 built 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.
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
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.

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](image-url)
**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.

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.
**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.

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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 halfway 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.

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 Zhuhai Link is part of the overall Hong-Kong - Macau – Zhuhai Link and has a length of some 14 km and consists of a bridge that runs from the Zhuhai-Macau BCF island towards the main land 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 key technical challenge is the tunnel underneath the China – Macau border crossing facilities.

**TEC’s scope of work**
Risk Assessment and development of risk control measures for design scheme and construction organisation of 3 alignments with a total of 6 configurations comprising Open-excavation top-down and Sub-surface excavation methods for the Gongbei BCF Tunnel section in preliminary design stage that included following content:

- Risk assessment and control measures for technical schemes for main works of the tunnel and for construction organization schemes for main works of the tunnel.
- Risk assessment and control measures for the design schemes of traffic engineering and auxiliary facilities (including rescue system) of the tunnel.
- The effect of tunnel technical schemes on operational management.

The Risk Assessment has been carried out in compliance with the China "Risk assessment guidance for highway tunnel safety" (Version for trial) complemented by International accepted risk assessment methodology.
Nijverdal, The Netherlands
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.