A journey underground.

TUNNELS & UNDERGROUND STRUCTURES

BOUYGUES TRAVAUX PUBLICS

Shared **innovation**

The strength of experience.

For more than 35 years, Bouygues Travaux Publics has been a major player in the tunnelling industry. Our business lines cover the design, construction, renovation and outfitting of tunnels as well as the excavation of caverns.

Skilled in all excavation techniques, we have built our reputation on our capacity to bore in complex geological terrain and to construct very large diameter tunnels.

Backed up by our network of academic and industrial partners, Bouygues Travaux Publics puts its trust in collective intelligence and provides its expertise over the entire construction value chain.

Channel Tunnel [France, 1993]

600 kilometres of tunnels on 5 continents.

Miami, Paris, Cairo, Doha, Hong Kong, Sydney...
Bouygues Travaux Publics has completed more than 100 projects, including 50 rail and 25 road tunnels.

Tunnels of varying diameters: ranging from 3.85 metres to 17.63 metres, with a world record achieved in Hong Kong in 2015. Tunnels for any type of use: public transport systems, road traffic tunnels, drinking-water supply, waste-water infrastructure, storage areas, utility tunnels and public utilities.

We are ready to rise to the challenges of the future: tunnelling into complex materials or water-bearing strata, boring in dense urban areas and excavating deep underground.

→

Port of Miami Tunnel [USA, 2014]

The tunnelling mindset.

Solidarity, autonomy and pride in a sense of belonging: the tunnelling mindset combines a passion for the work, a quest for technical excellence and a desire to pass on knowledge. Expertise and the values held dear by our teams combine to assist our clients on each of their projects.

Bouygues Travaux Publics has, for several years now, been deploying a dedicated underground-structures network in order to attract talented staff, foster mobility and develop skills. The training given to Tunnel Boring Machine (TBM) pilots, which combines theoretical input with practical in-the-field experience, is the cornerstone of our high-level performance.

Convinced that gender balance is a source of enrichment, we are also committed to the feminisation of our production teams with an objective of reaching a threshold level of 30% of women in management roles.

With our presence on all continents, Bouygues Travaux Publics and its 5,000 staff provide expertise for highly technical projects.

Construction using tunnel boring machines

Bouygues Travaux Publics is a **pioneer** in the use of tunnel boring machines. Ever since the boring of the Channel Tunnel, we have favoured this excavation technique, which combines speed, considerable cutting power, precise trajectory control and adaptability to whatever type of geology is encountered.

The tunnel boring machine is truly an **underground factory**, a versatile tool which excavates and installs precast concrete segments as it advances in order to construct the support for the ground and the permanent tunnel lining.

Bouygues Travaux Publics is skilled at using the whole range of excavation techniques according to the environment, the geology and any scheduling constraints:

- **Open-type hard rock TBM**
- **Slurry pressure balance TBM**
- **Earth pressure balance TBM**
- **Hybrid TBM**
- **Variable density TBM**
- **Multi-mode TBM**

Our success resides in our ability to **design**, adapt and equip tunnel boring machines in close cooperation with our scientific and industrial partners. This recognised expertise is based on the skills and experience of our technical department as well as a dedicated **creative** team. This is an advantage for our clients who are assured that their project will benefit from a customised machine, operated by skilled and specially trained teams.

AUSTRALIA **2000**

Sydney metro: New Southern Railway

Design and construction of a metro line as part of a Public-Private Partnership (PPP)

Carried out as part of a Public-Private Partnership, this **turnkey** 10-kilometre-long metro line, comprising 9 kilometres of tunnel and 5 new stations, connects Sydney city centre and Kingsford Smith Airport. Due to significant geological variations along the alignment, several excavation modes were used, including roadheaders for the hard rock and a bentonite slurry **shield** for the 5,500-metre-section of soft ground beneath the water table. At the time of construction, this 10.72-metre-diameter slurry-shield TBM was one of the largest of its kind. As one of the major infrastructure projects intended for the **2000 Olympic Games**, the line is now used by over 26 million passengers each year.

DIAMETER
10.72 m

LENGTH
5,500 m

USE
RAIL (METRO)

NETHERLANDS **2005**

Groene Hart tunnel

Design-build of a rail tunnel (high-speed line linking Antwerp-Rotterdam-Amsterdam)

To address technical and environmental challenges including an enormous **polder**, a tunnelling area below sea level, waterlogged subsoil, all in a protected region, Bouygues Travaux Publics came up with a decisive original solution: the construction of a single tube tunnel (7,160 metres) using the largest **slurry pressure balance tunnel boring machine** at that time (14.87 metres). The solution chosen by the Dutch Ministry of Transport, involving the building of a central partition wall, enabled the number of passages between the two tracks to be doubled. It also dispensed with cross passages, which are very difficult to build in sandy ground. Lastly, the area required for the access portal works and the volume of **excavated material** were significantly reduced, thus limiting the impact on the environment.

DIAMETER
14.87 m

LENGTH
7,160 m

USE
RAIL

HONG KONG 2009

Castle Peak cable tunnel

Design-build of a tunnel designed to house power cables

DIAMETER
5.22 m

LENGTH
4,500 m

USE
POWER
NETWORK

As part of an upgrade of Hong Kong's power network, CLP Power Hong Kong Limited appointed Dragages Hong Kong (a Bouygues Construction subsidiary) and Bouygues Travaux Publics to design and build a 4.5-kilometre-long tunnel linking the Black Point and Castle Peak power plants with Tuen Mun District. The tunnel houses 8 high-voltage cable **circuits** aimed at enhancing the reliability and efficiency of the power supply not just to Tuen Mun, but also to Hong Kong International Airport and the city of Tung Chung. Unprecedented challenges were involved in the project, including boring in close proximity to existing power cables and gas mains, advancing in highly variable geological conditions and rolling out radical environmental protection measures.

HONG KONG 2014

MTR 703 West Island Line

Construction of two rail tunnels (extension of the MTR West Island metro line to the new Sai Ying Pun station)

DIAMETER
6.4 m

LENGTH
1,208 m

USE
RAIL
(METRO)

Prior to constructing the two new rail tunnels, 1,208 metres in length with a diameter of 6.4 metres, it was first necessary to dismantle 150 metres of existing tunnel. The machine used was **a first of its kind**: the Tunnel Dismantling Machine (TDM), an innovative TBM that reversed the construction process. The TDM maintained a confinement pressure of three bars to enable dismantling of the existing segments and back-filling of the tunnel, in soft soil located below the water table in Hong Kong's city centre. The main advantage of this unique procedure was that it limited challenging dives in hyperbaric conditions by **mechanising** the process.

UNITED STATES 2014

Port of Miami tunnel

Design-build of a subsea road tunnel as part of a Public-Private Partnership (PPP)

∅ DIAMETER
12.85 m

LENGTH
1,260 m

USE
ROAD

This twin-tube 1,260-metre-long structure directly links the Port of Miami to the motorway without going through the town centre. The project was awarded as part of a Public-Private Partnership (PPP) signed with the Florida Department of Transportation and presented a major challenge: the subsoil was partly composed of highly porous **coralline limestone**. The TBM was therefore modified during manufacturing to provide two tunnelling operating modes: earth pressure balance and a hybrid mode called Water Control Process. A precursor to the variable density mode, this involves mucking out a hybrid earth pressure balance TBM using a hydraulic process. Prior to tunnel excavation the porous limestone was grouted from a barge to ensure stability during boring. Another feature of the project: the tunnel is equipped with four massive **flood gates** weighing more than 55 tonnes that can close and hermetically seal the structure within a few minutes in the event of a hurricane.

SWITZERLAND 2014

Weinberg tunnel

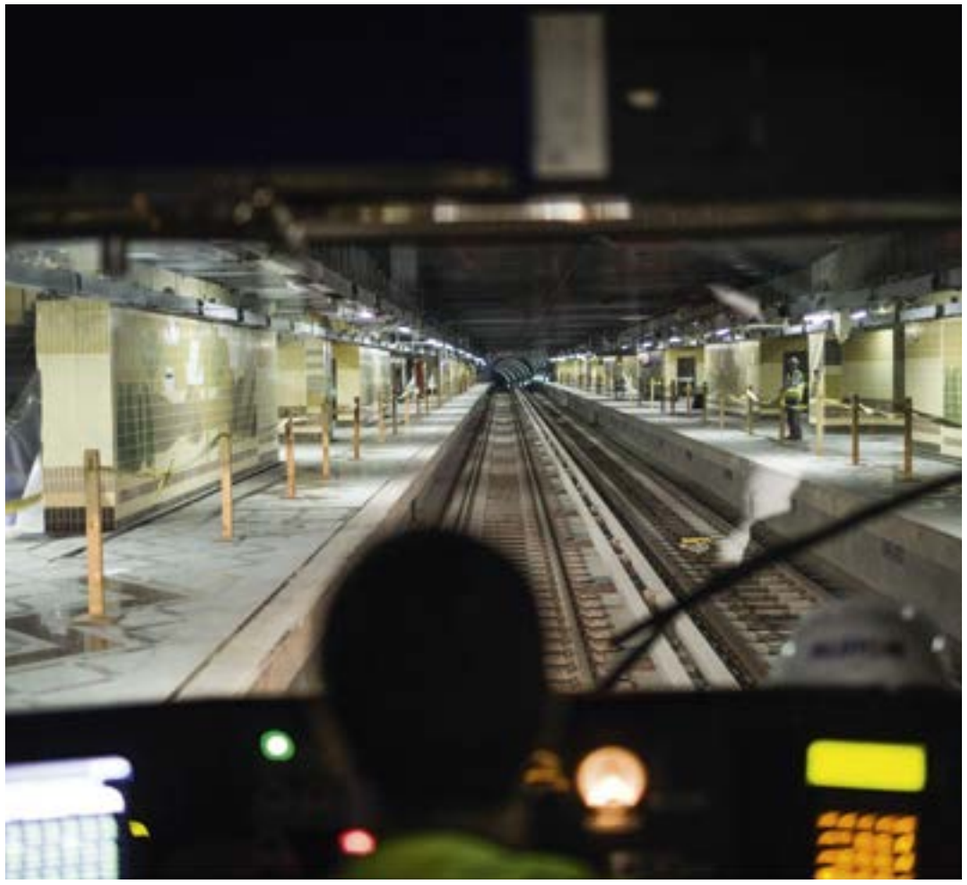
Design-build of a rail tunnel

∅ DIAMETER
11.3 m

LENGTH
4,200 m

USE
RAIL

The Weinberg rail tunnel, awarded by Swiss Federal Railways and the Canton of Zurich, involved the extension of Zurich's main station railway lines. The 4.2-kilometre tunnel crosses a dense urban area of listed buildings and passes beneath the main branch of the Limmat river. The tunnel, constructed by **PraderLosinger** without interrupting the station's operations, was bored using an 11.3-metre **mixshield tunnel boring machine** and required the conversion of the hard rock double shield to a slurry pressure double shield system to excavate the 280 metres of soft ground. The underground drive beneath the historic Südtrakt station required top-down mining in rock over a distance of 110 metres.



EGYPT 2019

Cairo metro

Design and execution of the civil works for line 3, phase 4A

DIAMETER
9.45 m

LENGTH
5,150 m

USE
RAIL
(METRO)

For over 35 years, Bouygues Travaux Publics has contributed to the development of the largest city in North Africa via the design and construction of the Cairo metro, as part of a Franco-Egyptian consortium. More than 80 kilometres of metro lines are already in service. Lines 1 and 2 linking the north and south of the capital have been finalised, whilst **line 3** is still partially under construction. In time, this line will connect the left bank of the Nile and Cairo Airport, running through the city from east to west, and will complete the existing network, serving 5 million passengers per day. In 2015 and 2016, the National Authority for Tunnels (NAT) again placed its trust in the consortium for the construction of phases 4A and 3 of the new line. Built in several stages and **phases**, the Cairo metro is confronted with challenges typically involved in TBM excavation projects: a densely populated urban area with intertwined networks, diverse ground conditions, and numerous passages under the Nile.

FRANCE 2019

Nice tramway

Design-build of a rail tunnel and underground stations
as part of the construction of the west-east line of the tramway

DIAMETER
9.66 m

LENGTH
3,082 m

USE
RAIL
(TRAMWAY)

More than 3 kilometres of tunnel, two shafts, four underground stations, a high-permeability subsoil, all in a very dense urban area: this is the challenge undertaken by the consortium led by Bouygues Travaux Publics in order to successfully complete the construction of the new tramway line for the city of Nice. The new 11.3-kilometre line will eventually link the port of Nice to the airport in less than 30 minutes. The stations are designed like underground car parks, using **diaphragm walls** and top-down excavation under cover slabs. Some 300,000 m^3 of excavated material, extracted by the slurry pressure balance tunnel boring machine, is transported to a **treatment plant** located within the port of Nice, then transferred by a conveyor system onto barges and taken away by sea for final dumping.

FRANCE 2019

Extension of the Paris metro line 14

Detailed engineering and construction of a rail tunnel (extension of the Paris metro)

DIAMETER
8.80 m

LENGTH
2,320 m

USE
RAIL
(METRO)

Bouygues Travaux Publics was entrusted with the civil works for the Clichy-Saint Ouen-Pleyel section and construction of the Mairie de Saint-Ouen station by the Parisian transport authority (RATP). In order to excavate the 2.3 kilometres of tunnel, divided into three short sections, the teams designed an **earth pressure balance tunnel boring machine** that is compact enough to be assembled and dismantled three times in the same 53-metre-long launch shaft. The double-track main tunnel is supplemented by a connection tunnel to the maintenance and storage site. Line 14, which departs from the heart of Paris, will in time join up with the future **Grand Paris** hub (Saint-Denis-Pleyel) and will decongest line 13.

HONG KONG 2020

Extension of the Shatin to Central Link metro line, contract no. 1128

Construction of 2 x 2 rail tunnels

DIAMETER
7.44 m

LENGTH
1,220 m

USE
RAIL
(METRO)

For the extension of the Shatin to Central Link metro line, connecting the New Territories in the north to the business district of the town centre, the Mass Transit Railway Corporation entrusted Dragages Hong Kong and Bouygues Travaux Publics with the construction works of 2 x 2 tunnels. To excavate close to the surface under a dense urban environment and cope with a complex geology, a **variable density TBM** was used – a first in Hong Kong. This new type of tunnel boring machine combines the advantages of traditional slurry pressure and earth pressure balance TBMs. It enables material density at the cutting face to be adjusted and to deal with a **wide variety** of ground conditions.

HONG KONG **2020**

Tuen Mun-Chek Lap Kok Link

Design-build of a subsea road tunnel linking the New Territories to the artificial island of Hong Kong-Zhuhai-Macau Bridge Hong Kong Port

The 5-kilometre-long Tuen Mun-Chek Lap Kok Link twin-tube tunnel will link the New Territories in the north to the artificial island of Hong Kong-Zhuhai-Macau Bridge Hong Kong Port, providing faster access to the international airport. The world's largest slurry tunnel boring machine (with a diameter of 17.63 metres) was used to drive an initial 600-metre-long section before being **converted** for the section of tunnel that narrows from three lanes to two. Once the shield and cutter head of the first TBM had been changed, two 14-metre-diameter machines advanced within a high-pressure environment, excavating 4.2 kilometres of subsea tunnels. With excavation areas reaching up to **50 metres** below sea level, maintenance operations were carried out in **hyperbaric conditions** by teams of specialised divers living at the surface in pressurised habitats.

∅ DIAMETER
17.63 m

LENGTH
5,000 m

/:\ USE
ROAD

FRANCE **2021**

Eole: RER E extension

Construction of a rail tunnel
(extension of RER E towards the west)

As part of the Eole project to extend the RER E rail network towards the west, the Bouygues Travaux Publics-led consortium is responsible for building the section linking the town of Courbevoie and the Haussmann Saint-Lazare station and for carrying out the civil works for the Porte Maillot station. Virginie, the **largest tunnel boring machine** currently operating in Greater Paris, is excavating 6.1 kilometres of tunnel up to depths of 43 metres. Linked to the TBM by a partially elevated **muck-removal pipe**, the "Base Seine" landing stage houses a sludge treatment unit and enables excavated material to be removed by barge. This temporary logistics platform minimises the impact of works on road traffic by eliminating the need for around 250 trucks to travel through the city every day.

DIAMETER
11.05 m

LENGTH
6,100 m

USE
RAIL
(METRO)

Construction using conventional methods

Excavating tunnels, access roads and caverns: in the depths of the earth, choosing the right tool is of critical importance. When encountering very hard rock, it is the **traditional** methods of excavation, tried and tested over time beneath the Alps, in Hong Kong and in Australia, that have forged the reputation of our tunnel builders.

Over more than 35 years, Bouygues Travaux Publics has acquired a solid **reputation** in the construction of tunnels using conventional methods. This expertise enables us to accurately meet the needs expressed and to adapt our solutions according to existing **geological conditions** and ground behaviour. After the pre-support works, excavation is carried out using various procedures:

- **Drill and blast:** a multi-armed drilling robot (known as a jumbo) drills blast holes into the rock face in order to load the emulsion explosive.

- **Roadheader machines:** an articulated arm with a rotating cutting head scrapes and cuts away at the tunnel face.

Once the tunnel has been bored, the ground is supported by fixing anchor bolts and using sprayed concrete. Even in a traditional context Bouygues Travaux Publics is **innovative** by providing continual monitoring of the thickness of the sprayed concrete.

FRANCE **1997**

Lyon North Ring Road

Financing, design-construction and operation of an urban expressway as part of a concession project

An 8.5 kilometre-long urban toll expressway, the Lyon North Ring Road links the A6 motorway to the East Ring Road, thus decongesting the city centre by directing the traffic under the Saône river and the Caluire hill. Completion of this gigantic **turnkey project** in a dense urban environment in only 38 months was an unprecedented challenge. The scope of work involved two twin-tube tunnels of more than 900 metres in length bored using explosives, one 3,250-metre tunnel bored in hard and abrasive terrain, a viaduct over the Rhône, three cut-and-cover sections and three interchanges. This project was considered **the largest** civil works construction site in France during the late 1990s. Several features attest to the modernity of the structure. The road surfaces have an anti-noise bitumen coating, and the communications system brings together the most recent technologies of the time in terms of CCTV, signage, ventilation, drainage and the fire protection network.

LENGTH
8,500 m

USE
ROAD

SWITZERLAND **2005**

Ferden Tunnel

Construction of the central section of the Lötschberg rail tunnel

The Lötschberg rail tunnel, a rail line providing an accompanied combined transport link between northern Europe and Italy, is part of the vast transalpine programme known as **AlpTransit**. At 2,000 metres below the summit of the Lötschberg, the Ferden tunnel, a central 7.7-kilometre-long section, is remarkable due its **enormous size**. The works required the installation of a powerful air-conditioning and ventilation system to deal with the high temperatures of the rock, which exceeded 47°C near the tunnel face, and relative air humidity of up to 100%.

LENGTH
7,700 m

USE
RAIL

FRANCE 2012

Toulon Tunnel

Construction of a road tunnel
(connection between the A50 and A57 motorways in Toulon)

LENGTH
1,800 m

USE
ROAD

In addition to being built in the city centre, in an area of old buildings with shallow foundations, this project was subjected to working in unpredictable and challenging geological conditions: very disturbed subsoil of rare geological complexity. The latter is characterised by a succession of extremely varied **geological strata**, like many piles of broken plates inserted between each other. The **GTA** – a suspended gantry rig equipped with drill arms and baskets for arch handling and placement – was used for the first time in France. In addition to saving space in this confined area, this type of machine also helps to ensure the safety of staff by keeping them at a distance from the tunnel rock face.

HONG KONG 2015

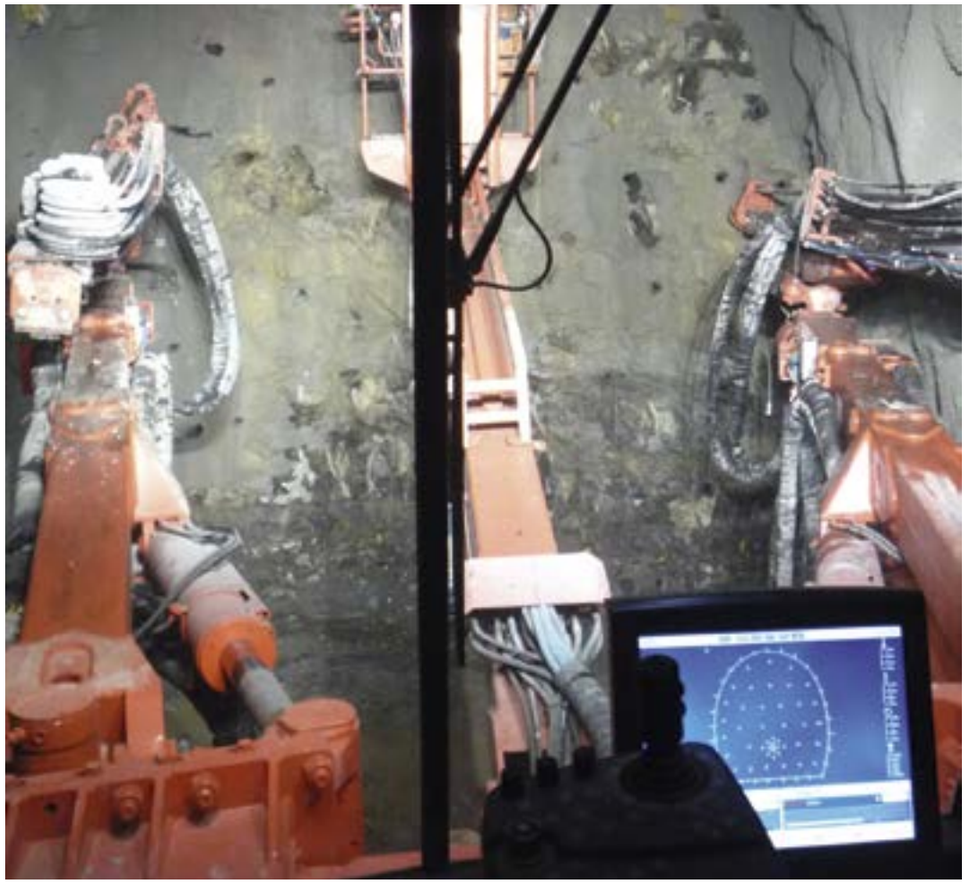
Express Rail Link contract 821: Shek Yam to Mei Lai Road tunnel

Construction of a rail tunnel
(Hong Kong-Guangzhou express rail line)

LENGTH
2,950 m

USE
RAIL

The Guangzhou-Shenzhen-Hong Kong express rail line links these three large Chinese cities with trains travelling at up to 300 kilometres/hour. For this project, the Dragages Hong Kong and Bouygues Travaux Publics joint venture blast-excavated an approximately 3-kilometre-long **single tube tunnel** (contract 821). A 3.5-kilometre twin-tube tunnel was also built using two tunnel boring machines for the section between Mei Lai Road and Hoi Ting Road (contract 820). A special feature of contract 821: a large-sized **cavern** where the junction tunnel meets the main tunnel.



SWITZERLAND **2016**

Hongrin-Léman underground hydropower house

Capacity increase of existing plant

LENGTH
1,500 m

USE
HYDRAULIC
(WATER CONVEYANCE)

In 2011, Forces Motrices Hongrin-Léman SA decided to increase the capacity of the existing hydroelectric plant by adding a new underground powerhouse. PraderLosinger was tasked with constructing the access tunnels, the headrace tunnel, the powerhouse cavern, the tailrace tunnel, the underground chambers, the shafts and a new surge chamber. In total, nearly 160,000 m^3 of spoil was excavated and recycled as concrete aggregate, filter drains and hardcore material for foundations. Excavation of the 56-metre-high, 100-metre-long **cavern** for the powerhouse, and the 1,500-metre-long tunnel, was carried out using a drill and blast technique. Since the site is located close to Lake Geneva, with part of the structure below the water level, it required significant **grout injection**.

HONG KONG **2019**

Liantang road tunnel

Design-build of two motorway tunnels, a ventilation structure and an administrative building

LENGTH
4,800 m

USE
ROAD

To connect the New Territories of the north-east of Hong Kong to the Liantang border crossing in mainland China, the public authorities decided to have a 5.4 kilometres dual two-lane road built, including two 4.8-kilometer tunnels. In order to deal with changing ground conditions along the route Bouygues Travaux Publics and Dragages Hong Kong combined their expertise using several excavation techniques. A first in the history of the group: the widening by **excavator** of a tunnel section previously bored by TBM. This increase in the diameter from 14 to 17 metres enhances **visibility** at the tunnel entrance and thus improves safety for future users.

AUSTRALIA **2020**

NorthConnex motorway link

Design-build of a twin-tube motorway toll tunnel

In Australia, in northern Sydney, Bouygues Construction Australia is constructing a 9-kilometre, dual three-lane motorway tunnel that will link the M1 and M2 motorways. Taking advantage of the predominately **sandstone** geology, 17 roadheader machines brought in from the mining industry are used for the excavation. The topographical surveys are performed using a scanner and data is transmitted to the surface via Wi-Fi. The drill holes for the permanent tunnel equipment support anchors in the ceiling are machine-drilled using the in-house designed **Roby 850** robot.

LENGTH
9,000 m

USE
ROAD

Refurbishment and outfitting of tunnels

In a tunnel, a wide **range of equipment** ensures the safety of its users and the optimal operation of the structure. Providing services throughout the life cycle of the structure, Bouygues Travaux Publics specifies, installs and maintains safety and operating equipment such as:

- **Cross passages** and safety niches
- **Signage,** illuminated signage and safety lighting
- **Fire protection** and smoke-control ventilation systems
- **Wire or radio communications** networks and power
- **CCTV** and automatic alarm systems
- **Pumping** and storm water collection networks

All of these services are part of a very strict regulatory framework aimed at ensuring a high level of safety. Bouygues Travaux Publics therefore delivers high-performance, reliable underground structures on a **turnkey** basis for its clients. Our in-depth knowledge of the infrastructure being operated, together with our capacity to work on an occupied site, enable us to propose an integrated offering for the assessment, **repair** and reinforcement of structures: tunnel enlargement, repointing of masonry, drain reconstruction and upgrading to fire safety standards.

In the refurbishment and upgrading market, Bouygues Travaux Publics provides its expertise through risk control and **multidisciplinary management**. By supervising all of the interfaces, we ensure the consistency of the project as a whole for our clients.

FRANCE 2008

Mont-Sion tunnel

Design-build of a road tunnel as part of the concession contract for the A41 motorway

DIAMETER
11.9 m

LENGTH
3,100 m

USE
ROAD

The Mont-Sion tunnel is a major component of the A41 North motorway linking Annecy to Geneva. It is made up of two 3,100-metre-long tubes bored using an open shield TBM with a diameter of 11.9 metres. Each tube accommodates two 3.5-metre traffic lanes, an emergency lane and two walkways. Beneath the road slab a precast service gallery, accessible to maintenance personnel, houses the tunnels' electrical and mechanical equipment. In case of tunnel evacuation, user safety is enhanced by a series of **cross passages** located every 400 metres connecting both tubes (4 for pedestrians and 3 for road traffic). To comply with stringent fire safety **standards**, 74 fire safety niches were built in each tube and a powerful smoke extraction system was installed.

FRANCE 2010

Fréjus rail tunnel

Modernisation of a rail tunnel to comply with European standards

FIRE POINTS
31

LENGTH
7,000 m

USE
RAIL

The Fréjus rail tunnel, or Mont-Cenis tunnel, is located on a strategic axis for European trade linking Dijon to Turin via Modane. To increase the transit of passengers (Paris-Milan) and goods, Réseau Ferré de France entrusted Bouygues Travaux Publics with the modernisation and the **enlargement** of the 7 kilometre-long French section of the Fréjus tunnel to comply with new European standards. Upgrading works consisted of lowering the tunnel's ground level and re-centring the rail tracks, all whilst keeping up with continuous rail traffic circulating on a 14 kilometre-long tunnel. The creation of safety niches made it possible to experiment with a new technique, **Expansive Foam Demolition (DMX)**, which avoids the use of explosives.

SOUTH AFRICA **2011**

Gautrain Rapid Rail System

Financing, design-build, operation and maintenance of a rapid rail system as part of a concession contract

Delivered on schedule for the FIFA World Cup, the rapid rail system linking Pretoria to Johannesburg was the completion of the most significant **PPP** project in which Bouygues Travaux Publics has ever participated in the African continent. This colossal project, which involved 54 months of works, 15 kilometres of tunnels, 9 kilometres of civil engineering structures and 10 underground and overground stations, was also the first **integrated rail project** led by Bouygues Travaux Publics. In addition to the technical challenges faced, particularly in greenfield land with complex dolomite geology, this project stands out for its **environmental** accomplishments: conservation of displaced trees, limitation of noise, recycling of water and mining waste. A comprehensive initiative recognised at the Green Supply Chain Awards in 2009.

STATIONS
10

LENGTH
15 km

USE
RAIL

FRANCE **2014**

A14-A86 motorway underground complex

Design and execution
of safety improvements
for a motorway complex

As part of the **modernisation** programme of 22 tunnels in the Paris area, initiated in 2009 by the French government and the highway authority for Greater Paris, the A14/A86 consortium (led by Bouygues Travaux Publics) carried out safety improvement works on the tunnels in the Nanterre-La Défense complex. The contract involved building four new emergency escape routes with exits to the surface, improving the accessibility of refuges and existing emergency exits, installing **fire protection** boards throughout the tunnels, increasing the smoke venting capacity, and fitting CCTV and radio communications equipment. Carried out at night, the installation of 300,000 m^2 of calcium silicate boards on all of the side walls and ceilings of the tunnels maintains the structural integrity of the tunnels in the event of fire, thanks to a powerful **heat shield**.

FIRE RESISTANT BOARDS
300,000 m^2

LENGTH
15 km

USE
ROAD

SWITZERLAND **2015**

Simplon tunnel

Upgrading, renovation and structural reinforcement of a 100-year-old rail tunnel

LENGTH
19.8 km

USE
RAIL

Nearly 20 kilometres long, the Simplon tunnel, linking Switzerland to Italy, is one of the world's longest rail structures. Swiss Federal Railways awarded PraderLosinger a contract involving the upgrading to current standards of this twin-tube, single-track tunnel, brought into service in 1906. Thanks to tailored logistics and project phasing, all of the **renovation works** were carried out whilst maintaining rail traffic services: refurbishment of the electrical and drainage systems, reinforcement and enlargement of the tunnel structure, lowering of the invert, renewal of the ballast, and expansion of the niches housing technical equipment. These works enabled not only rail traffic **safety** to be improved, but also both tubes to be upgraded.

FRANCE **2018**

L2 Bypass

Design-build, finance, maintenance and renewal of the road infrastructure and equipment as part of a Public-Private Partnership (PPP)

LENGTH
10.9 km

USE
ROAD

Since the 1930s, Marseille has had the objective to decongest traffic in the city centre by providing a north-east **road alternative**, linking the A7 and A50 motorways. The construction of the 10.9-kilometre L2 bypass was completed thanks to the works carried out by a consortium of companies led by Bouygues Travaux Publics and ordered by the Société de la Rocade L2. Modernisation of this motorway involved the installation of **innovative equipment** such as automated traffic management systems as well as automatic detection of road incidents, transportation of hazardous materials, and outsized vehicles.

Immersed tube tunnels

When it comes to river or sea crossings, a wide variety of structures are possible: bridges, excavated tunnels or **immersed tube tunnels**. The latter have the advantage of integrating more easily into constrained spaces, as they require lower gradient approach tunnels and allow navigation to continue during the works.

Bouygues Travaux Publics uses this method by combining its recognised expertise in the field of **maritime and river works** with appropriate nautical resources. Not quite a tunnel, not quite a maritime structure, the immersed tube tunnel is an economically and technically appropriate solution for medium length or extra wide crossings.

The steps in the construction process have been widely tried and tested:

- **Earthworks on the river or sea bed**
- **Precasting on dry land** of the watertight concrete caissons in an enclosed area or on a wharf
- **Floating** and towing into place
- **Immersion**
- **Assembly of caissons** and making the joints watertight

In spite of it being a time-tested procedure that was used for the first Metro lines under the River Seine at the beginning of the 20th century, the building of an immersed tube tunnel remains a technical exploit even to this day. The construction of such complex infrastructures which are, in reality, **underwater bridges**, is an opportunity for Bouygues Travaux Publics to demonstrate the strength of its experience.

FRANCE **1987**

Nogent-sur-Marne underwater crossing

Construction of two underwater road tunnels
(A4 and A86 motorway link at Nogent-sur-Marne)

CAISSON WEIGHT
4,000 to 6,000 t

LENGTH
210 m
(WEST CARRIAGEWAY)
140 m
(EAST CARRIAGEWAY)

USE
ROAD

The two immersed tunnels enable the A86 motorway to cross the Marne river in two separate tubes, with a length of 210 metres for the west carriageway and 140 metres for the east carriageway. They are composed of seven precast, pre-stressed concrete **caissons**, floated into place and then submerged. In order to build the concrete supports on the Marne riverbed on which the caissons are grounded, major **dredging works** were required. To avoid the use of explosives, the company designed a "suction" dredger equipped with a hydraulic arm for rock extraction. In this way, all of the works were carried out without interrupting river traffic on the Marne.

GERMANY **2003**

Rostock tunnel

Design-build of an immersed road tunnel as part of a concession project

CAISSON WEIGHT
22,000 t

LENGTH
790 m

USE
ROAD

Located 250 kilometres north of Berlin, the industrial port of Rostock is cut in two by the estuary where the Warnow river flows out into the Baltic Sea. To link the two riverbanks, the city awarded Bouygues Travaux Publics a 30-year concession for a **fixed crossing** of the river. An immersed tube quickly emerged as the most appropriate solution. **Six caissons** were therefore precast on dry land. Closed at both ends, they were floated and towed into place before being immersed one by one, and then connected. The temporary bulkheads were then removed to form a 790-metre-long single tube.

UNITED KINGDOM **2011**

New Tyne Crossing

Design-build of a new road tunnel, renovation of an existing tunnel, construction of an interchange and two toll plazas as part of a Public-Private Partnership (PPP)

The New Tyne Crossing in Newcastle, opened to the public in early 2011, doubled the capacity of an existing road structure inaugurated in 1967, thus enabling decongestion of a key route for north-south traffic between Scotland and England. The project, spanning 2.5 kilometres, highlights the breadth of expertise of Bouygues Travaux Publics: an immersed tube tunnel made up of **four pre-stressed concrete caissons**, earthworks, road works and traditional tunnels, including two tunnels bored using SCL (Sprayed Concrete Lining). Without interruption to the Tyne river traffic, the existing cast-iron segment tunnel was also upgraded to current **standards**, particularly in terms of lighting, signage, drainage and ventilation. Both the old and new road structures now benefit from, amongst other things, a water mist system for **active fire protection**, a first in the UK at the time.

CAISSON WEIGHT
10,000 t

LENGTH OF IMMERSED TUNNEL
360 m

USE
ROAD

Shared innovation.

Innovation is at the heart of our culture and performance. Far from just being a trend, we are convinced that creativity, in the commercial phase or serving the work sites, is a competitive and technical factor that makes us stand out.

By building up a capital of ideas and by encouraging on-going improvement, innovation strengthens the reliability of our solutions, the quality of our structures and the safety of all those who work on our construction sites.

As players in the digital transformation, more than 600 engineers and technicians specialising in concept studies, detailed design and methods as well as in R&D and creativity, are looking towards a more open and mobile world.

→

Telemach, Safety Initiative of the Year [International Tunnelling Association (ITA) Tunnelling Awards, 2017]

Innovation, why do we do it?

To adapt to the functional requirements of the structures

To reduce the environmental footprint of the works

To meet complex technical constraints

1st

simulator in the world for TBM pilots, Thalia, was developed by Tunnel Lab teams.

MOBYDIC +

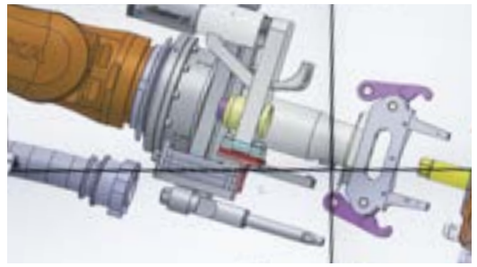
The pilot's eye

A decision-making assistance tool enabling TBM operation and maintenance to be optimised. Thanks to sensors incorporated into the disc cutters of the TBM cutterhead, data received (temperature, rotation, force) allows the operators to monitor the geology of the excavation face in real time (detection of caverns, constructions, concrete piers) and to optimise the excavation and **maintenance** of the tools.

PIPE-JACKING MACHINE +

A specialised tool

A mini tunnel boring machine which enables the production rate of **cross passages** to be improved. These passages cross-connect the tubes of an underground structure to provide an evacuation route for users in the event of emergency. Faster and more reliable than the traditional ground freezing method, the pipe-jacking machine maintains the structural integrity and watertightness of the main tunnels whilst considerably reducing completion times.



TELEMACH +

Remote controlled maintenance

An articulated robot enabling the **disc cutters** on the cutterhead to be changed, thus reducing human intervention. The use of Telemach reduces the occurrence of chronic illnesses associated with diving in hyperbaric conditions as well as the risks linked to the external environment. This innovation demonstrates that the robotic industry, when adapting to the conditions of underground working spaces, can contribute to improving staff health and safety.

ROBY 850 +

Automated drilling

Drilling and anchor robot, capable of accessing all tunnel wall surfaces. Thanks to its six-axis robotic arm it moves **automatically** from one task to the next: sanding, bush hammering, drilling, cleaning and fitting anchors in 90 seconds whilst memorising each action to ensure trackability. Roby 850 also adapts to and identifies joints between tunnel segments, relocating with a high degree of accuracy and complying with the layout plan.

We love life.

Protecting the health and safety of our staff, as well as that of everyone else who works on our sites, is our primary responsibility.

On all of its sites, Bouygues Travaux Publics deploys the best worldwide standards whilst also meeting the specific risks associated with underground works: operating in restricted and confined spaces, hyperbaric diving, fire risk and management of emergency services, concurrent activities and workflow management.

Safety is everybody's business: this means being vigilant at all times in order to ensure that our working methods are efficient and complied with.

→

World Health & Safety Day [Challenger, 13 June 2017]

Objective: zero accidents.

- Training and empowering staff in order to limit high-risk behaviour
- Improving the ergonomics of work stations to reduce the occurrence of musculoskeletal issues
- Checking up on the efficiency of initiatives through an assessment system shared by the whole company

40%

of the training hours carried out in our training plan are devoted to health and safety.

HEALTH AND SAFETY FUNDAMENTALS +

HEALTH AND SAFETY DAY +

SAFETY SURVEYORS +

WARM-UP SESSION +

A high level of commitment

Protective equipment, traffic, risk analysis and ergonomics information... 12 standards are applied to all construction sites in order to ensure the safety of all. At Bouygues Travaux Publics **specific working methods** for underground works, such as access checks to the tunnels and shafts along with personnel and plant flow plans, complement these H&S standards.

Raising the awareness of all

Dedicated workshops, information sessions, sharing of good practice: Health and Safety Day is a **worldwide awareness-raising event** during which all of those working on our construction sites, our staff and partner companies interrupt their work in order to share the common wish to achieve the "zero accidents" objective.

On the look-out on our construction sites

These staff are responsible for checking that safety regulations on every construction site, both in France and abroad, are complied with on a day-to-day basis. Safety Surveyors are authorised to **stop any work** which presents a serious breach of safety regulations or to recommend the exclusion of any person behaving dangerously in order to ensure optimal working conditions throughout the world and to enable a reduction in the number of construction site accidents.

Starting work safely

A daily team **warm-up session** to get muscles moving so as to reduce musculoskeletal problems. This new practice, coupled with a briefing presenting the jobs to be done during the day and things to watch out for, gets the body and the mind ready for the start of a shift and prevents sprains and stiffness whilst reinforcing team cohesion.

Throughout the world, our teams are committed to innovating and creating value for our clients.

As a subsidiary of Bouygues Construction specialised in civil works and structural engineering, Bouygues Travaux Publics is a global leader in the construction of sustainable public infrastructure enhancing regional development.

TUNNELS
& UNDERGROUND
STRUCTURES

RIVER
& MARITIME WORKS

BRIDGES

INDUSTRIAL CIVIL
ENGINEERING

LINEAR
PROJECTS

REFURBISHMENT
& REINFORCEMENT

EARTHWORKS

OPEN CAST
MINING

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BOUYGUES TRAVAUX PUBLICS

Shared **innovation**