WORLD CLASS TUNNEL SOLUTIONS

COMPREHENSIVE AND INNOVATIVE SERVICES FOR UNDERGROUND WORKS

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Creating sustainable connections

Ramboll has 50 years’ experience bringing innovative major crossings to life such as the iconic Øresund Fixed Link between Denmark and Sweden.

Our major crossings track record includes the Queensferry Crossing, the world’s longest three-tower cable-stayed bridge, and the Fehmarnbelt Link, which is on course to become the longest combined road and rail immersed tunnel in the world.

We provide clients with expertise across the entire infrastructure life cycle, from cradle to grave covering early stage concept and feasibility studies to detailed design, through to operation and maintenance design as well as construction follow up.

Our complete service comprises all the design, engineering, environmental, sustainability, and project and cost management skills needed for any type of major crossing. We add value to projects by offering specialist supplementary services such as lighting, ventilation, fire safety, mechanical & electrical engineering, and access strategies.

We are experienced in bringing together large teams of internal and external specialists to deliver the best solutions. Our integrated multidisciplinary approach is combined with a passion for innovative design to provide clients with inspiring, safe, sustainable, and cost-effective infrastructure.

We pride ourselves on working closely with our clients to fully understand and meet their individual needs. We work as a trusted partner to contractors in design and build or design and construct, with public authorities in more traditional design roles, and in PPP projects offering the full technical support service to complement the financial modeling.

ABOUT RAMBOLL

Ramboll is a leading engineering, design and consultancy company founded in Denmark in 1945.

The company employs 13,000 globally and has especially strong representation in the Nordics, UK, North America, Continental Europe, Middle East and Asia-Pacific.

With more than 300 offices in 35 countries, Ramboll combines local experience with a global knowledge base constantly striving to achieve inspiring and exacting solutions that make a genuine difference to our clients, the end-users, and society at large.


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COMPREHENSIVE TUNNEL ENGINEERING EXPERTISE

We provide professional consultancy services within tunnelling and underground works - from major international transport infrastructure for road and rail to small diameter microtunnelling works. We bring together tunnel experts with our specialists in other areas to deliver fully integrated solutions.

Ramboll’s tunnel engineers are proud to be international and work on all types of projects, with all levels of complexity.

Because Ramboll is an independent company, we can choose our work and therefore, our tunnel engineers have a very varied project portfolio. We work on micro to macro scale projects worldwide. Even a few hours of advice has proven to give an enormous benefit to our clients.

Our dedicated tunnel teams deliver the very best immersed and hard rock tunnel designs by drawing on multidisciplinary services and world class knowledge. Our expertise covers tunnels for metro systems, railways, roads, highways, storm and rain water, cyclists, pedestrians and utilities including power and cooling/heating.

In short, we have the in-house skills to cover the design of all types of tunnels. Our core tunnel skills are providing services for immersed and bored tunnels. As examples, we specialise in the design of immersed tunnels and their construction interfaces, international constructability advice (CA) for major tunnel projects, segmental lining design for bored tunnels, and damage risk assessments for structures in urban areas.

Our specialist skills include tunnelling under and close to existing structures, providing permanent diaphragm walls and using a range of top-down and bottom-up methods.

Our number of Ramboll transport and infrastructure specialists worldwide is 2,600.

01 Fehmarnbelt fixed link, Denmark-Germany
Ramboll is acting as lead consultant to Fehmarn A/S for the world’s longest rail/road tunnel, a role we have undertaken since 2006. This 18 km long immersed tunnel will greatly reduce the travel time between Scandinavia and mainland Europe.

02 Södra Länken, Sweden
Södra Länken is the longest road traffic tunnel in Sweden, and the second longest urban motorway tunnel in Europe. Ramboll delivered the design for 13 km of tunnels, operation rooms, rock reinforcement, sealing and drainage systems, geological survey and provided technical support during construction. The tunnel has served to reduce traffic congestion, direct traffic around Stockholm and enhance environmental conditions.
With the growth of population of urban areas globally, there are increasing demands on infrastructure and surface space: the option of locating this beneath the ground is becoming more common. In cities, where there are often many constraints at or near the surface from buildings, infrastructure and utilities – tunnels constructed using tunnel boring machines are an efficient, safe and cost-effective option for a range of soft and hard ground conditions.

Ramboll has experience in the delivery of bored tunnel projects across a range of diameters and in varying ground conditions – from major rail and metro systems to smaller utility tunnels. Our size and range of skills allows us to provide expertise for the design and construction of both the tunnels themselves, but also the wider system and operational aspects.

Our designers have expertise in the design of segmental linings for tunnels, including the use of fibre reinforcement – and we recently contributed to the internationally-recognised guidelines on the use of fibre reinforcement for tunnels published by the International Tunnel Association.

We have advanced expertise in aspects of tunnelling in urban areas, where control of ground movements and impacts on existing infrastructure can be critical to the design – our engineers have wide international experience in damage risk assessment and development of novel design solutions to limit the impact of ground movements.

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01 Parallel Thimble Shoal tunnel, USA
Tender design services for a major highway project in Virginia, USA. Ramboll provided key input in the sequencing and design for the TBM launch shaft which was located on an artificial island. Ground improvement techniques were proposed to minimise the shaft and TBM cover at launch.

02 Paris Metro, France
Ramboll provided expert advice and third-party review services for the design of steel fibre reinforced concrete segments for proposed bored tunnel works.

03 Confidential bored tunnel project, Turkey
Ramboll acted as Expert Reviewer services for a bored tunnelling project, where the complex ground conditions had caused significant issues during the tunnel construction.
Ramboll possesses the knowledge and experience within all relevant technical fields related to immersed tunnels, for all stages from the early studies and planning to the detailed design. We also assist our clients with construction follow-up, supervision, independent checking and maintenance.

Designing immersed tunnels requires close co-ordination between the structural design, and ground engineering, and the design of tunnel installations. Ramboll provides highly skilled structural engineers who work closely together with our tunnel installation and services specialists.

We recognise the importance and need for minimising and optimising space requirements for installations in order to keep the total construction costs low. However, it is equally important to provide the necessary space for the efficient future operation and maintenance of the tunnel. Our experience from operation and maintenance of Danish tunnels, has given us a unique insight into this area.

Furthermore, the need for implementing state-of-the-art safety concepts and well-planned escape routes is evident.

Ramboll has specialists within ventilation, fire-fighting systems, drainage, power supply and distribution, and our experience and services also cover control and management systems, passenger flow simulations, emergency escape simulations, traffic management, intelligent Transport Systems (ITS), tunnel lighting, IMT etc. For transport projects, we are able to complement our skills with our specialists in highway and rail to provide a full-service offering.

**60%**

Proportion of the world’s immersed tunnels that Ramboll has contributed to over the last decade.

**01 Øresund Fixed Link, Sweden-Denmark**
Ramboll led the consultancy team for the combined road/rail connection between Denmark and Sweden – this included a 3.5 km immersed tunnel, a 4 km artificial island and a 8 km bridge.

**02 Shatin to Central Link, Hong Kong**
Ramboll acts as the Expert Reviewer for the 1.7 km immersed tunnel crossing Victoria Harbour. The tunnel is constructed within complex ground conditions including a potential geological fault; our experts have provided high-value, pragmatic advice to assure the design and construction are undertaken within acceptable levels of risk.

**03 Sydney Harbour Tunnel, Australia**
Ramboll is providing services in asset management for the Sydney Harbour Tunnel, constructed in the 1990s. This includes the implementation of the SMART web-based asset management system (developed by Ramboll) which enables active management of the O&M activities throughout the life of the tunnel.
UNDERGROUND METRO WORKS

Growing city populations require public transportation solutions that are cost-effective, reliable and sustainable. Such demands can be met through well planned and designed metro and light rail systems.

Over the past 20 years, Ramboll has helped deliver underground metro and light rail across the globe. This has included roles in planning and procurement, alongside detailed design and construction supervision services. Our experts provide high quality services in the design and delivery of both civil works and tunnelling packages, and the rail systems works.

Our diverse experience and skills have allowed us to successfully deliver significant aspects of global mega-projects such as Crossrail and Copenhagen Metro. We take a holistic approach and provide multidisciplinary consultancy services from regional and comprehensive planning to detailed design of railway infrastructure.

We have expertise in all areas of civil works for underground metros, including bored tunnels, underground structures and alignment. We are also able to offer a full-service provision in-house for station design, including specialist services such as evacuation modelling and CFD analyses to optimise station layouts.

01 Copenhagen Metro
Nordhavn extension, Denmark
As part of the expansion of the Copenhagen Metro, Ramboll has provided multidisciplinary planning, design and supervision services to Metroselskabet since 2012 on the design and execution of the branch off to Nordhavn – comprising 3 km of track including 1.9 km of twin-bored tunnels, a new underground station and an elevated section.

02 Moscow Metro Lublinsko-Dmitrivskaya SCL Access Tunnel
Ramboll undertook the detailed design of the first sprayed concrete lining tunnel in Russia. This project provided our client with a successfully executed SCL tunnel and enabled the future use of the construction method elsewhere on Moscow Metro.

1,000
Number of multidisciplinary Ramboll experts contributing to metro projects
Ramboll has provided engineering and consultancy services for the development of the Copenhagen Metro since 1994. Our experts provided services from the initial planning phases of the network, and they continue to support the delivery including the most recent expansions due to be completed in 2024.
ROCK TUNNELS, MICROTUNNELLING AND PIPEJACKING

Through our international portfolio, our staff provide expertise across all types of tunnelling techniques including rock tunnels and microtunnelling.

Our experience in the Scandinavian market, with its wide-ranging geological conditions means that we are familiar with both drill-and-blast methods and the use of roadheaders. This experience in the design and construction supervision of rock allows us to advise clients and contractors alike across all projects stages. We have significant expertise in rock mechanics and numerical modelling that enables us to develop economic solutions for construction.

We have capabilities in design and construction of small diameter tunnels - through both in jacked tunnels and micro-diameter TBM works. In many cases, wider considerations have required these to be undertaken at very shallow depths and through challenging ground conditions; our experience and advice has enabled these to be undertaken successfully.

01 Damhusledningen, Denmark
Ramboll provided technical services to Hofor for the design and construction of a new stormwater drainage system in Copenhagen. This included sections of micro-TBM tunnelling, pipejacking and excavations for interceptor chambers.
Ramboll developed a conceptual design and options study for a new bypass in Fujairah, UAE. This included options for drill-and-blast rock tunnels and large rock cuts – for all aspects of the civil engineering works, including assessments of operational and maintenance aspects.

Ramboll was responsible for the design of 7 km of tunnels for high-speed rail in between Holm and Holmestrand in Norway, including the station at Holmestrand - located in a mountain. The station has had unique challenges with regards to acoustics and air, due to high air pressure from the high-speed trains passing through the tunnel and hall.
**VERIFICATION AND INDEPENDENT CERTIFICATION**

Ramboll has experience in undertaking roles on tunnel projects where an independent role is required.

We have experience in undertaking roles as Independent Checker (Category III) where detailed calculations and analyses are required, to Independent Safety Assessor (ISA) and Design Verifier roles requiring a more risk management approach to be undertaken.

The engineering expertise gained in other roles as designer and client consultant allows our staff to objectively assess the requirements of these roles and help guide the overall approach to design closeout in an effective and pragmatic manner without compromising on risk management.
Ramboll undertook an independent check (Category III) of the detailed design of the Shannon River crossing, comprising designs of permanent and temporary structural works, mechanical and electrical works and the Intelligent Traffic System.

Ramboll is responsible for the independent checking (Category III) of the western section of the Thames Tideway tunnel – including a range of tunnels (segmentally lined, SCL and pipejacked) and associated underground works for shafts, as well as strengthening works for existing structures.

The Green Line forms part of Doha’s new metro system, which is a key delivery for the 2022 FIFA World Cup. Ramboll is the Design Verification Engineer for the project, bringing together expertise both in Qatar and across the company as a whole. Ramboll is providing services across all disciplines for the civil works including tunnelling, structures, geotechnical, MEP and architecture.
Scandinavia and the rest of Europe will in the near future be connected by the world’s longest immersed road and rail tunnel, between Rødby in Denmark and Puttgarden in Germany. Ramboll is the main engineering consultant on the Fehmarnbelt Fixed Link, one of Europe’s biggest infrastructure projects and expected to open to traffic in 2028.

The fixed immersed tunnel link across the Fehmarnbelt will be more than 18 km long and incorporate a four-lane motorway alongside a twin track-electrified railway. The fixed link will reduce the travel time between Scandinavia and Continental Europe.

At a speed of 110 km per hour, this will offer motorists a journey time of approximately 10 minutes through the tunnel. For train passengers, the journey will take seven minutes from coast to coast. The duration of a train journey between Hamburg and Copenhagen will be cut short from about four and a half to merely three hours.

The immersed tunnel solution under Fehmarnbelt required innovative thinking, as it challenges existing tunnel building standards. It improves functionality through its pioneering longitudinal ventilation system and state-of-the-art safety and security features.

The immersed tunnel will be more than five times the length of the tunnel under Øresund linking Denmark and Sweden, and more than three times the length of the Trans-Bay Tube BART Tunnel in San Francisco in California, the current world record holder.

Designing immersed tunnels is all about optimising resources. After immersion, the free space in tunnel elements needs to be ballasted with concrete. For this reason, the tunnel elements have been designed with limited space to ensure absolute minimum resource use.
As a new concept in immersed tunnel technology and design, the underwater link is constructed from 79 standard and 10 special elements to allow for a traffic deck and a maintenance deck. Systems for electricity, communication, monitoring and drainage take up space and require maintenance. These are integrated in special elements on a lower level beneath the traffic routes, thus allowing easy access for personnel without disrupting traffic.

The safety concept features two-lane traffic for motorists, a full emergency lane and emergency doors every 110 metres to make escape routes visible and easily accessible in the event of a major accident. A simple, resilient and reliable longitudinal ventilation system with jets will fan the tunnel at 400 metre intervals and is based on a new design approach that considers future EU standards for reduced car emissions.

The tunnel consists of two road tubes with a two-lane motorway in each, a central gallery for escape and service and two railway tubes. Each concrete element can float, meaning that in the immersion phase the water’s own lifting power will carry the 217 metre-long elements, each weighing up to 73,500 tonnes. The tunnel will be sited safely below the seabed, protected against ship anchors and other collisions.

Throughout the tunnel, users will pass illuminated zones ranging from lilac to blue, green and yellow. These zones will help keep drivers alert and indicate how far they have travelled. LED lighting will also meet motorists as they enter, drive through and exit the tunnel. The lighting will form one-minute moving motifs along one of the tunnel walls. Altogether, the lighting experience will give the tunnel a sense of open space, resembling changing landscapes along normal roads.

The design aesthetics of a tunnel concealed 40 metres below sea level can easily be overlooked. However, landscape architects have been involved to help design a natural travel experience in which commuters from both sides of the tunnel will crest a hill for a full sea view before dipping down into the bowl-shaped tunnel entrance.

**FEHMARNBELT AT A GLANCE**

- Length of tunnel: 18 km
- Journey time through tunnel: 10 minutes by car, 7 minutes by train
- Construction budget: US$ 9.1 Billion
- Expected opening to traffic: 2028
FEATURE PROJECT

CROSSRAIL, LONDON

Ramboll has provided expertise across a full range of services helping deliver Europe’s largest infrastructure project on time and on budget. Our staff have worked on a range of design packages and construction contracts ranging from bored tunnels to archaeology, underground stations to oversite developments.

UNDERGROUND WORKS

Bored tunnels
42 km of bored tunnels have been constructed under Central London; these tunnels have been designed to carry full gauge rail, and will carry 200 million passengers every year. Our engineers were able to help protect around 4,000 buildings and over 10,000 existing utilities, from ground movements caused by excavation works.

Our experience in using complex soil structure analyses allowed us to reduce the number of structures requiring strengthening or mitigation works due to the works.

Through our extensive local experience, our engineers undertook detailed characterisation of the ground and geological modelling of the chalk to help manage risks during construction and assess the maintenance over the lifetime of the tunnels.

Paddington station
Ramboll provided detailed design services for the new underground station at Paddington, constructed using diaphragm walls and a top down sequence. Close monitoring of the surrounding ground and heritage structures were vital, as was the construction sequence interface with the bored tunnelling contract.
Custom House station
Ramboll provided full design services for the new Custom House station, detailing the novel concept of using an exposed pre-cast concrete structural frame solution developed using Design for Manufacture and Assembly principles and provided multidisciplinary design services while working closely with Crossrail to integrate the complex project’s developing needs into the detailed design.

Tottenham Court Road
Ramboll provided full engineering design services for the oversite development (OSD) at the western underground ticket hall. Our engineers have developed specialist vibration isolation measures to insulate the residential development from the operational station below.

Intervention shafts
Ramboll provided MEP design services for three intervention shafts, and was responsible for the integration of the building services elements of the shafts and the coordination with the system wide contractors including traction power and tunnel ventilation.

Sprayed concrete lining (SCL)
14 km of platform tunnels and connecting passenger tunnels have been constructed to form a range of underground structures for stations, cross passages and concourses. Our staff provided expert advice regarding sprayed concrete linings and non-linear three-dimensional analysis used during the design process to account for the complex geometry and soil structural interaction.

Archaeology
Our specialists provided archaeological services to Crossrail during the construction stage for the western central section of the works.
GLOBAL EXPERIENCE
LOCAL KNOWLEDGE

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