RAMBØLL

INSPIRING BRIDGE SOLUTIONS

WWW.RAMBOLL.COM/BRIDGES

Ramboll is a global engineering, architecture, and consultancy company based in Copenhagen, Denmark. The company was founded in 1945 and has since expanded to over 300 offices in 35 countries. Ramboll offers a wide range of services in areas such as buildings, transport, energy, environment and health, water, management consulting, and more.

The company has a focus on sustainability and aims to create long-term value for its clients and society as a whole.

www.ramboll.com

17,000 PEOPLE
300 OFFICES
35 COUNTRIES

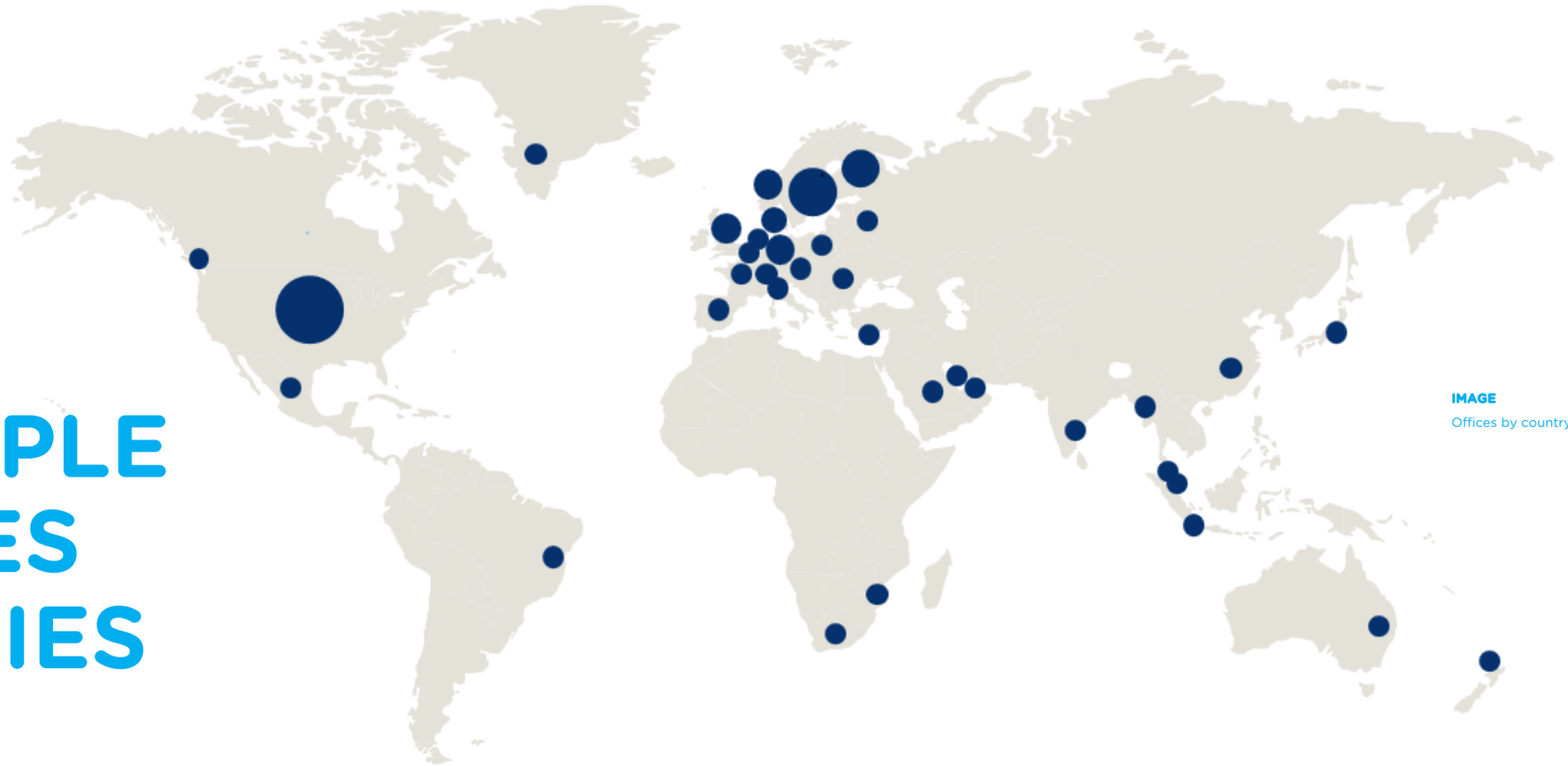

IMAGE
Offices by country

BUILDINGS
Buildings form a fundamental part of our lives by shaping our communities and daily activities.

For these reasons, Ramboll's design philosophy is to always make room for the human experience. As one of Europe's top 3 buildings designers with decades' of experience in the global market, we create visionary, sustainable, and award-winning buildings that improve life for users and enhance the surrounding landscape.

Read more at:
www.ramboll.com/buildings

ENERGY
Security of power supplies, climate change, energy efficiency and resource scarcity are top priorities on the global agenda.

Ramboll is at the forefront of addressing these issues as the global market leader in offshore wind, waste-to-energy and district heating consulting and the leader in Scandinavia for large-scale thermal power consulting. We also have a specialist competence in designing power transmission masts and offshore wind met masts.

Read more at:
www.ramboll.com/energy

ENVIRONMENT
Industrial development, urbanisation, the extraction of natural resources and extreme weather events all call for sustainable and responsible environmental solutions.

As the leading environmental consultancy in Northern Europe and one of the top-20 globally, Ramboll's environment experts help customers across the mining, water, buildings, transport, energy, and oil & gas markets to address these issues. We take a comprehensive view of each project to optimise every step of the process and deliver solutions that are technically resilient, environmentally sustainable, and valuable to society.

Read more at:
www.ramboll.com/environment-and-health

WATER
Water is essential to life and one of our most precious resources. Working with municipalities, utilities, and industrial clients Ramboll draws on proven multidisciplinary expertise to manage the most challenging water resources, wastewater, and storm water issues. We integrate treatment process selection and engineering, operational services, and regulatory management and planning to deliver innovative solutions that benefit both industries and society.

Read more at:
www.ramboll.com/water

PLANNING & URBAN DESIGN
Ramboll's holistic approach to urban development encompasses strategy, planning, and world class technical design services and is based on an integrated multidisciplinary skills base.

We have an extensive track record working with a number of the world's largest cities to create liveable, sustainable, and implementable urban development solutions that are fully adapted to the local context.

Read more at:
www.ramboll.com/planning-and-urban-design

MANAGEMENT CONSULTING
National, regional and local authorities are responsible for issues that affect us all; from health care, education and day care to strategic planning of infrastructure and climate initiatives. Drawing on 500 management experts, Ramboll acts as a trusted partner to public administrations, creating the insights needed to make informed strategic decisions that promote stronger societies.

With unprecedented levels of competition in the global economy, Ramboll focuses on empowering private sector customers with expertise and powerful management tools. Read more at:

www.ramboll.com/management-consulting

TRANSPORT
Mobility fuels economic and social development and with 50% of the world's population now living in urban areas, efficient and reliable transport systems are essential.

To meet this need, Ramboll has been working on some of the world's largest, most innovative infrastructure projects and is the leading consultancy in the Nordic market. We create value for transport authorities, contractors and local authorities by providing multidisciplinary technical excellence and minimising resource usage.

Read more at:
www.ramboll.com/transport

BRIDGE SERVICES
Ramboll's multi award winning bridge team is at the forefront of bridge design. Our experience spans small pedestrian bridges through to major crossings, with many of our designs becoming landmark structures. We provide all the design, engineering, environmental, sustainability, and project and cost management skills needed across the entire bridge lifecycle.

BRIDGES
ABOUT US

OUR TEAM

We have 17,000 people in 300 offices across 35 countries

OUR CLIENTS

Our clients include bridge operators and owners, contractors, developers, local authorities and government bodies.

We are renowned for our world class bridge portfolio. Our passion for design and clever engineering drives creative, efficient, safe and sustainable construction.

As a leading sustainable society consultant, we ensure our solutions successfully serve and connect societies, now and in the future.

Our expertise and portfolio

We provide the full range of multidisciplinary design, engineering and consultancy needed for any bridge type. We deliver feasibility studies and concept design, foundation design, hydraulic analysis and construction management. We are essential partners, from project beginning to project end, and beyond.

Our impressive repertoire of bridge projects over the course of 60 years is a testament to our team's imagination and ambition to deliver inspiring structures that not only deliver functionally but also create a sense of place. Our portfolio ranges from major crossings to small pedestrian bridges, and from designing brand new bridges to strengthening those that already exist.

We are involved in the UK's three largest new estuary crossings. Ramboll has led the design joint venture for the Queensferry Crossing, was lead technical consultant and now part of the technical advisory team for the Mersey Gateway, and independent checker for the New Wear Crossing.

MERSEY GATEWAY

The Mersey Gateway, a 6 lane cable-stayed toll bridge, is a visually stunning solution to strategic transport needs in the north west, acting as a powerful statement of regional pride and ambition. Images: Mersey Gateway Crossings Board.

OUR APPROACH

PRACTICAL, EFFICIENT AND CREATIVE DESIGNS

ESSENTIAL COMPONENTS

The essential components of all our work involve three elements to deliver well-designed structures:

- Structural Integrity – delivering sound and well-designed structures
- Practical Design – ensuring all functional needs are met
- Elegance – producing aesthetically pleasing designs

Design excellence
The variety of our designs reveal our imaginative approach and robust process. Every bridge design is a meticulous response to the context: location, material and usage. Aesthetic demands, function and appearance come together in the final design.

While we are responsible for many iconic bridges around the world, we are equally proud of our simpler and smaller scale bridge designs.

Innovative culture
Our rich heritage in innovation has advanced best practice in bridge design throughout the industry. We designed the world's first tilting bridge, the Millennium Gateshead Bridge, and the dramatic and unique 'Twin Sails' bridge in Poole. We have leading experts in concrete and steel technologies as well as in dynamic analysis and response suppression of cable supported structures. We apply this expertise to some of the world's most challenging bridge structures, such as the spectacular proposed Sulafjorden Bridge on the E39 in Norway.

Forming close relationships
We have strong ties with leading architects, planning authorities and statutory bodies, and we've proved we know what it takes to work successfully in integrated teams. You'll find us collaborative, communicative and completely engaged.

Sustainable outcomes
Ramboll is committed to creating solutions that deliver a sustainable future, enabling people and nature to flourish. We measure success not only by how well our clients are served, but also by how well bridge users and surrounding communities are served. We deliver progressive solutions that bring both commercial advantage and sustainable outcomes.

TWIN SAILS BRIDGE
This visually stunning bridge in Poole Harbour resembles the sails of a yacht when the two spans are lifted, providing a clear 19m channel for boats to pass. Image: Dave Morris Photography.

IMPROVING LIVEABILITY THROUGH MOBILITY

Mobility is key to liveability in the 21st century. The creation of new bridges and the safeguarding of existing ones is critical for the improved flow and freedom of vehicles, people and goods. They can act as catalysts for economic regeneration and improved quality of life. We understand the broader role bridges can play and are skilled in creating integrated, sustainable transport solutions that are sensitive to their settings.

QUEENSFERRY CROSSING
The Queensferry Crossing is one of the most striking engineering icons of the twenty-first century. It is the UK's tallest bridge and the world's longest three-tower, cable-stayed bridge. Linking Edinburgh with the county of Fife it sits alongside its illustrious neighbours, the Forth Bridge and Forth Road Bridge. Image: Bastian Kratzke. Courtesy of Transport Scotland.

OUR SERVICES

INTEGRATED MULTIDISCIPLINARY DESIGN, ENGINEERING AND CONSULTANCY

OUR SERVICES:

- Planning
- Feasibility studies
- Outline proposals
- Preliminary design
- Detailed design
- Tender
- Construction engineering
- Operation and maintenance
- Repair
- Strengthening
- Demolition or replacement

Through the Project lifecycle
Our team of bridge engineers and designers bring expertise in safety, design, construction and operation gained from more than 60 years working on international bridge projects.

Work ranges from concept design of new bridges through to design of repair and strengthening solutions for existing bridges, including design of temporary works for bridge maintenance and replacement.

With world class transport and infrastructure expertise spread across the globe, we combine local knowledge with international teamwork. Ramboll provides design, analysis, and project and cost management services, helping our clients imagine and realise sustainable solutions.

Understanding performance to minimise disruption
Bridges are critical pinch points in any transport network. Working closely with clients, we design major bridge works that can be carried out with minimal impact on trains or road traffic, easing disruption to bridge users, local communities and businesses.

With skills in assessing, strengthening and managing aging infrastructure, coupled with experience of specialist design and construction techniques, we design lasting solutions to critical transport needs.

CIRCLE BRIDGE
Ramboll was the full-service consultant for the detailed Cirkelbroen moveable bridge in Copenhagen's inner harbour.

OUR SERVICES

A fresh approach to bridge safety
Assessment of bridge safety is a complex process. Sometimes, bridges with apparent problems can be shown to be safe. In contrast, bridges with hidden defects might be unsafe and yet may have historically been assessed as 'adequate'.

To properly assess bridge safety we use a combination of advanced analytical techniques and thorough structural behaviour investigations. In recognition of this approach, Ramboll was awarded the Historic Bridges Award for not (sic) strengthening Winston Bridge.

Ramboll has increased the assessed capacity of well over 100 bridges, many from zero live-load to full assessment loading. Supporting Network Rail with the management of their bridge stock, we delivered many refurbishment, strengthening and renewal projects and have overseen the assessment of 2,000 bridges in the past 20 years.

We use innovative techniques to assess buckling, yielding and concrete behaviour, ensuring interventions are appropriate. Our development of advanced discrete element analysis of masonry arches earned Ramboll the Queen's Award for Enterprise: Innovation. We assessed the influence of the construction of the Shard on the extensive masonry vaults below London Bridge Station. And we preserved the world's first iron bridge using our innovative process that links laser surveys with analysis. We can also offer non-destructive testing techniques on road networks to assess stability and structural integrity.

Sustainable solutions to meet regional needs
We deliver designs for iconic new infrastructure, such as Gateshead Millennium Bridge and Twin Sails in Poole, as well as designs that re-use existing bridge infrastructure such as Bermondsey Dive Under and Northern Hub. These help to boost regional economic competitiveness by connecting communities with reliable and sustainable transport solutions.

IRON BRIDGE
Ramboll conducted modelling, analysis and assessment of Iron Bridge, the world's first iron bridge, together with a desk study of the development of structural defects. Image: Roger Davies.

MAJOR BRIDGES

Today’s major bridges are becoming ever more sophisticated. Ramboll has been closely involved in modern developments of major bridges which have seen cable-stayed structures grow from modest scale footbridges to much larger crossings, previously only the domain of suspension bridges.

CHAMPLAIN BRIDGE
The New Champlain Bridge Corridor is one of the largest and most strategic corridor-wide projects in North America. Image: Signature on the Saint Lawrence.

MAJOR BRIDGE PROJECTS

01 MERSEY GATEWAY
Mersey Gateway is a six lane cable-stayed toll bridge and the second largest estuary crossing under construction in the UK. It will reduce journey times for millions of people and attract massive inward investment and regeneration in the region. Supporting Mersey Gateway since 2001, Ramboll's initial role as lead technical consultant helped secure funding approval. Then in 2014 our work continued as part of a technical advisory team, to support the Mersey Gateway Crossings Board with the technical and contractual administration of the project. Image: Mersey Gateway Crossings Board.

02 STOREBÆLT EAST BRIDGE
As a leading expert in major bridge inspections, Ramboll carried out inspections and rehabilitation works on the Storebælt East Bridge, also known as the "Great Belt Bridge" in Denmark. Designed by Ramboll and built in 1998, the bridge has a main span of 1.6km and side spans of 535m giving an overall length between the two anchor blocks of 2.7km. The bridge is connected to 23 approach spans with the pylons being one of the highest points in Denmark.

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03 QUEENSFERRY CROSSING
This new UK cable-stayed road bridge linking Edinburgh with the county of Fife sits alongside its illustrious neighbours, the Forth Bridge and Forth Road Bridge and is the UK's tallest bridge. We are proud to have led the Design Joint Venture on this Transport Scotland project. Ramboll has brought many innovations to the project, one example being a significant change to the design of the foundations which helped to de-risk the construction programme and deliver material cost savings. Image: Graeme Peacock, Courtesy of Transport Scotland.

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04 FARRIS BRIDGE
E18 Bridge and motorway was the largest and most prestigious project in Norway. It replaced 6.4km motorway that no longer met the needs of up to 17,000 daily road users. The new four-lane motorway and bridge stretches alongside Farris reservoir - a source of drinking water for 200,000 inhabitants. In addition to designing the bridge Ramboll, in collaboration with L2 Architects, drew on the multidisciplinary team of experts in wastewater, environment, geology, geotechnics, landscape architecture, construction monitoring, zoning, ventilation, noise pollution and impact analysis to ensure successful delivery of the project and minimal environmental impact.

05 NEW CHAMPLAIN BRIDGE CORRIDOR
As the Independent Engineer for the New Champlain Bridge Corridor, one of the largest and most strategic corridor-wide projects in North America, Ramboll's role is to review the bridge designs, including the crown-jewel of the project, the New Champlain Bridge. The 3.4km crossing over the main channel of the St. Lawrence River includes a cable stay section over the St. Lawrence Seaway, and is a replacement for the decaying Champlain Bridge. Image: Signature on the Saint Lawrence.

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MOVING BRIDGES

Moving bridges present many design and engineering challenges. As compact electromechanical structures with short spans that open to river traffic when required, moveable bridges are appropriate for locations where there is limited land available. Our team of experts have the engineering experience and knowledge to fully understand the challenges associated with moving structures.

GATESHEAD MILLENNIUM BRIDGE
Gateshead Millennium Bridge was the world's first tilting bridge. Our competition winning design, in collaboration with Wilkinson Eyre, provided an iconic structure over the River Tyne to celebrate a new era. Image: Ramboll.

MOVING BRIDGE PROJECTS

01 TWIN SAILS BRIDGE
This visually stunning bridge in Poole Harbour resembles the sails of a yacht when the two spans are lifted, providing a clear 19m channel for boats to pass. The 'Twin Sails' Second Opening Bridge spans the navigation channel of the Backwater Channel. It comprises a 10.8m wide carriageway incorporating two vehicular lanes segregated from two cycle lanes, with two 2.5m wide footpaths that cantilever from the bridge. The 139m long bridge has five spans that lay flat when closed. Image: Dave Morris Photography.

02 GATESHEAD MILLENNIUM BRIDGE
Gateshead Millennium Bridge is the world's first tilting bridge. Our competition winning design, in collaboration with Wilkinson Eyre, provided a new crossing over the River Tyne and an iconic structure for the new millennium. Using its inventive pivoted solution, the architecturally stunning structure overcame constraints with its geometric simplicity and was a catalyst for regeneration. The Royal Mint chose the bridge for a commemorative one pound coin, sitting alongside bridges designed by Telford and Brunel. Image: Ramboll.

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03 MEDIA CITY FOOTBRIDGE
This footbridge forms a part of the Salford Quays regeneration that links the Media City development with Trafford Wharf. Together with our partners we created a bridge that met the dual 20m headroom requirements for ships and achieved "landmark" designation. The design detail extended to every element of the bridge; from the cable-stay anchorages featuring cantilevered seating benches and the visually deceptive angle of the bridge edge soffit; to the discrete stainless steel gate 'pods' and precise selection of lighting. Image: Inside Out.

04 PONT Y DDRAIG – RHYL HARBOUR
The landmark Pont y Ddraig also known as the Rhyl Harbour Bridge is an important access point for the National Cycle Route 5 for all types of sustainable transport, tourism and leisure users. Pont y Ddraig is a twin bascule style opening bridge, allowing the passage of boats and yachts. Twin 32m glass and carbon fibre composite decks lift through a cable system located within a 50m high stainless steel mast resulting in a dramatic lifting sequence. Image: Ramboll.

05 CIRKELBROEN – THE CIRCLE BRIDGE
Ramboll was the full-service consultant for the detailed Cirkelbroen moveable bridge in Copenhagen's inner harbour. The pedestrian and cycle bridge can open for larger boats sailing through and consists of five differently sized circular platforms, each with its own mast. The moveable part consists of three circles, with only the largest circle in the centre of the bridge resting on the seabed. When the bridge opens, the middle platform will rotate on its axis.

06 CATHEDRAL BRIDGE
Designing the pedestrian and cycle swing bridge over the River Derwent in Derby gave our team the opportunity to extend bridge technology. The bridge has an iconic needle-shaped mast to echo the heritage of the nearby Silk Mill. A 38m main span and 18m kinked back span is supported by three pre-stressed cables. The bridge rotates on a central pivot bearing under the mast while the tail end bearing is continuously supported on a concealed track. Image: Lightworks Photography.

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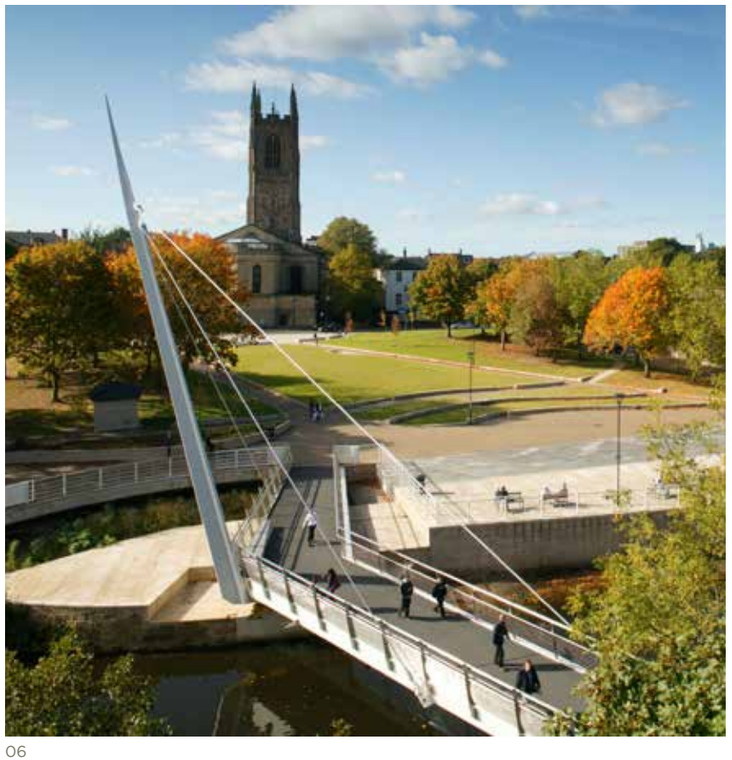

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PEDESTRIAN BRIDGES

Pedestrian bridges have an inherent significance and symbolism as connectors and conduits, gateways and meeting places, landmarks and icons. We design safe and aesthetically pleasing crossings. Many become landmark structures in their own right, whilst others serve their purpose simply and honestly.

JARROLD BRIDGE
The Jarrold Bridge is an award-winning double cantilever footbridge linking St James Place to the historic city centre of Norwich in the UK. Image: Jaap Oepkes.

PEDESTRIAN BRIDGE PROJECTS

01 JARROLD BRIDGE
The award-winning Jarrold Bridge is a double cantilever footbridge. Spanning the river Wensum it improves pedestrian and cycle access to Norwich city centre and the railway station, whilst maintaining passage for river traffic. The primary design concept was for a bridge that traced a smooth uninterrupted arc over the water. The result is this unique bridge form that appears to float over the site with little visible means of support. Designed for fabrication offsite, the deck was craned into position, minimising disruption to the river banks and traffic. As well as providing engineering services, Ramboll undertook a full ecological programme to protect the local indigenous wildlife. Image: Jaap Oepkes.

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02 SPINNINGFIELDS FOOTBRIDGE
The Spinningfields footbridge provides a safe, car-free crossing linking the Manchester and Salford banks of the River Irwell. It was designed with particular attention to the needs of cyclists and disabled users, and is an exceptional piece of contemporary engineering. The bridge consists of an underslung cable catenary supporting a structural steel deck with lightweight aluminium decking. At the centre of the main span the deck is a generous 4.5m wide and includes an 8m long bench. Image: Jaap Oepkes.

03 FORTHSIDE PEDESTRIAN FOOTBRIDGE
Binding together two disparate places, the Forthside footbridge provides pedestrians with a link between Stirling's city centre and a new development area on the banks of the River Forth. It acts as a visual signal contrasting the modern with the old. The dramatic, visually 'light' design uses inverted trusses to support the deck from above. This asymmetrical arrangement creates an organic twisting form, spanning seven rail tracks, a service road and a car park. Ramboll provided the structural, lighting and mechanical design for the bridge. Image: Paul McMullin.

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04 GOLDEN JUBILEE BRIDGES
We designed the Golden Jubilee footbridges that sit aside the Hungerford Railway Bridge, providing safe walkways across the River Thames, linking the South Bank with Charing Cross and the West End. Each footbridge comprises a seven-span cable-stayed structure hung away from the railway bridge on tapered tubular steel pylons. At 4m in width the decks cater for the heavy pedestrian traffic across the river. The competition-winning design includes ship impact protection for the historic rail bridge caissons from Brunel's suspension bridge of 1845.

05 CYKELSLANGEN
Copenhagen's new, elevated cycle lane known as 'Cykelslangen' connects the Vesterbro and Islands Brygge districts providing an alternative route for the cyclists using Bryggebroen as a gateway to the island of Amager. The bridge, previously a missing link for cyclists, is suspended 5m above pedestrian walkways and up to 7m above sea level. Constructed out of steel, the 190m long and 4m wide bridge has a 30m ramp creating a shortcut for cyclists crossing the Port of Copenhagen.

06 AKROBATEN
We are proud to have designed the Akrobaten bridge, the 206m long pedestrian and cycle bridge in Norway, that runs across the tracks of Oslo Central Station connecting Bjørvika to the city centre. Cutting-edge in design, the bridge is made of steel and glass and has become a popular subject for photography and films. The backbone of the bridge is a triangle truss weighing 180 tonnes. The steel and concrete gangway is supported in the truss by 72 hangers.

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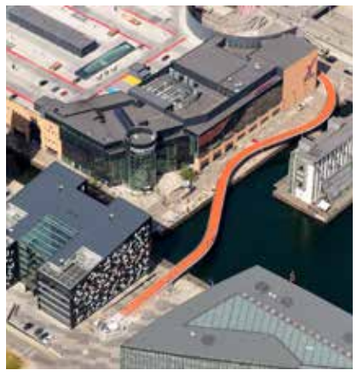

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STRENGTHENING, REFURBISHMENT AND MANAGEMENT

Ramboll is an internationally recognised expert in assessing and strengthening aging infrastructure. Our renowned non-standard design and assessment approaches have facilitated challenging strengthening projects instead of conventional replacement of structures, saving our clients millions of pounds.

We provide world class expertise in areas such as post-tensioning, the realistic assessment of structures, failure modes effect and criticality analysis, finite/discrete-element method, engineering simulation and 3D computational design. This means we can safely maximise the capacity of existing structures.

HAMMERSMITH FLYOVER
As part of our work on the TfL Structures and Tunnels Investment Portfolio (STIP), our innovative strengthening solutions have extended the life of the Hammersmith Flyover by installing the first ever full new pre-stressing system where it was not possible to remove the original without significantly disrupting the traffic on this critical route. Image: Daniel Shearing.

SAVING BRIDGE PROJECTS

01 POST-TENSIONED CONCRETE BRIDGES
Over 40 years Ramboll has carried out more than 90 special investigations of post-tensioned concrete bridges. Our design of the new post-tensioning system for Versova Creek Bridge in Mumbai and Hammersmith Flyover in London are the latest major strengthening projects in a portfolio that includes the Braidley Road Bridge tendon replacement, and the M8 Kingston Bridge strengthening (illustrated) with the largest diameter post-tensioning cables ever used in an existing bridge at the time. We tailor solutions to address specific challenges and constraints with 'progressive strengthening' that ensures the integrity and safety of a structure is improved at each successive stage of the works. Image: Ramboll.

01

02 HISTORIC METAL BRIDGES
We have assessed and strengthened more than 40 historic metal bridges in the UK, gaining a thorough understanding of their behaviour. Intelligent and sensitive blending of historic and modern standards, and techniques, has allowed us to develop solutions that are sympathetic to the fabric and appearance of these structures. Our award winning approach to refurbishing the complicated structure of Coalport Bridge (illustrated) resulted from months of complex analysis. Our calibrated 3D model identified strengthening works needed. Image: Daniel Shearing.

02

03 GLOBAL HIGHWAYS INFRASTRUCTURE
Globally there is an increasing sense of urgency regarding the management and care of aging infrastructure: optimising safety, improving reliability and reducing lifetime costs. Our projects have enabled increased capacity, transportation sustainability and regional economic competitiveness. Examples include the widening of UK motorway bridges on the M1 and M9, developing standards for the management of 11,000 post-tensioned concrete bridges in Japan for NEXCO (illustrated), and strengthening design and investigation of the Varsova Bridge in India. Image: Polfoto.

04 COST SAVING FROM NOVEL APPROACHES
Using advanced analysis we have assessed as 'adequate' many half through girder bridges, saving unnecessary strengthening or replacement. On the DLR 3-car enhancement (illustrated) we substantially reduced the scope of fatigue strengthening works by monitoring actual stresses. Image: Daniel Shearing.

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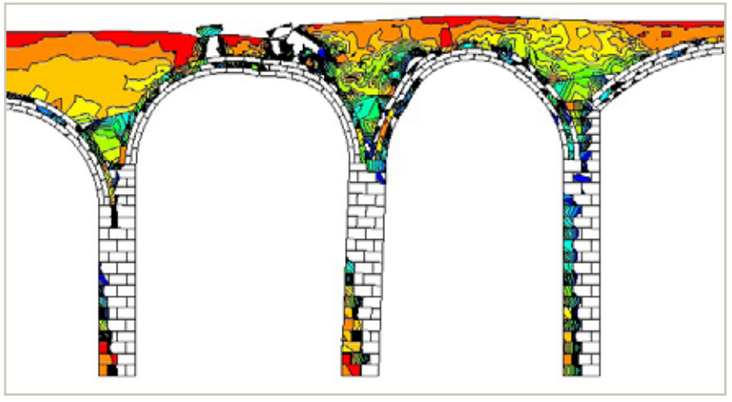

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05 MASONRY ARCH BRIDGES
We developed advanced discrete element analysis of masonry arches (illustrated) which led to 350 'ARCHTEC' strengthening projects from 1998 to 2016 and won a Queen's Award for Enterprise: Innovation. Discrete element analysis enables much more rigorous assessment of the real behaviour of masonry structures, justifying increased strengths and facilitating more novel and efficient strengthening solutions. In 2007 we created a structural model with 13,500,000 degrees of freedom to assess the impact of the construction of the Shard on the extensive masonry vaults below. Image: Ramboll.

06 RAIL BRIDGES
We have supported Network Rail in managing their bridge stock for over 20 years, assessing thousands of bridges, developing standards and guidance, and delivering numerous refurbishment, strengthening and renewal projects. For Northern Hub we are assessing the capacity of masonry arch viaducts and other bridges, designing strengthening where required. At the Bermondsey Dive Under (illustrated), a key junction, developed designs for new viaducts using the existing foundations, reflecting the form of the remaining structures, while optimising the use of precast offsite manufacture. Image: Skanska.

06

REGENERATING URBAN LANDSCAPES

CYKELSLANGEN BRIDGE
Copenhagen's new, elevated cycle lane known as 'Cykelslangen' connects the Vesterbro and Islands Brygge districts providing an alternative route for cyclists using Bryggebroen as a gateway to the island of Amager. Image: dissing+weitling.

RAMBØLL

Bright ideas.
Sustainable change.

Read more

Image: Graeme Peacock
Courtesy of Transport Scotland