

Keeping Immersed Tunnels Watertight for 120 Years



Contents



Contents

CASE STUDIES:

TRELLEBORG'S TUNNEL TIMELINE	6
CONNECTING DENMARK AND SWEDEN ØRESUND LINK, DENMARK - SWEDEN	8
SECOND CHANCE AT INCREASING ACCESSIBILITY SECOND COEN TUNNEL, AMSTERDAM, THE NETHERLANDS	10
REDUCING CONGESTION, SEALING SAFETY MIDTOWN TUNNEL, HAMPTON ROADS, USA	12
A FIRST FOR MEXICO COATZACOALCOS TUNNEL, COATZACOALCOS, MEXICO	14
UNDERWATER CONNECTION IN STOCKHOLM SÖDERSTRÖM TUNNEL, STOCKHOLM, SWEDEN	16
THE WORLD'S LONGEST LINK HONG KONG-ZHUHAI-MACAU BRIDGE, HONG KONG - CHINA	18
IMMERSED IN RAIL SHA TIN-CENTRAL IMMERSED TUNNEL, HONG KONG - CHINA	20
A PORT UNDER PRESSURE MARIEHOLM TUNNEL, GOTHENBURG, SWEDEN	22

Keeping Immersed Tunnels Watertight for 120 Years

Sealed for success: time-tested sealing systems in action.

Growing urbanization into major cities means our current infrastructure is under intensifying pressure as people migrate from one place to another and need access to new locations. The impact of climate change and ever-rising water levels also means many environments are at a much greater risk of flooding and seismic movements, which existing systems, such as immersed tunnels simply can't withstand. It's now more important than ever that we modernize existing structures and build new ones that can endure high water pressure and make even the most extreme environments more accessible to our growing population. As the world's leading supplier of total sealing systems for immersed tube, bored and cut and cover tunnels for over 50 years, Trelleborg's

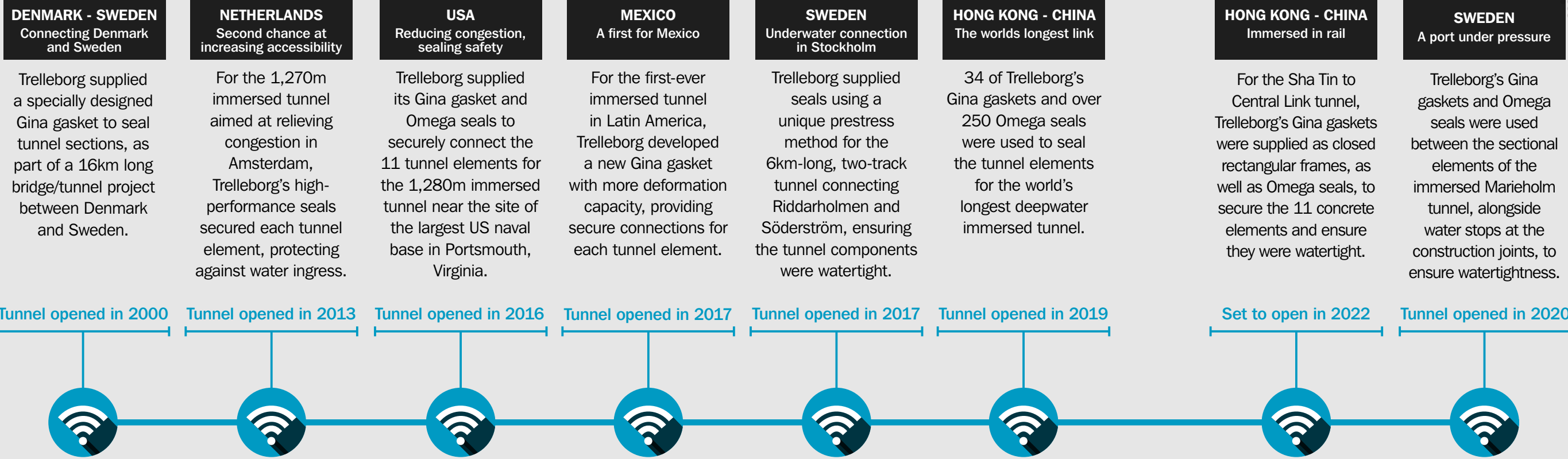
sealing systems are one of the few solutions that protect against water ingress and extreme movements. The flexibility, durability, and 120-year expected lifespan of our polymer solutions place us as the leading partner for the design and manufacture of reliable sealing systems that can stand the test of time and support the long-term integrity of new structures.

Take a look at some of the most exciting projects we've been part of and delve deeper into our tailor-made engineered solutions in some of the most technically complex and challenging environments.



Sealed for success

A timeline of Trelleborg's recent tunnel projects



Connecting Denmark and Sweden

Øresund LINK Denmark, Sweden

Problem: For many years, the Strait of Øresund was a barrier to transporting goods and people between Denmark and Sweden. To improve ease of access, and increase commercial opportunities, a better link was needed between the two cities, and so construction began on the world's longest cable-stayed bridge.

Challenge: A 3.5km long immersed tunnel was constructed to bridge a connection between Denmark and Sweden. The tunnel included 20 precast concrete elements, each weighing 55,000 tonnes, which connect the artificial peninsula at Kastrup to the man-made island in Strait of Øresund.

Solution: The Gina gasket was vulcanized on site due to logistical challenges. The vulcanization was implemented in a container under a conditioned environment.

A Gina gasket with a hollow soft nose was required to initially seal against an uneven concrete surface and required for a low reaction force and a relatively large initial compression.



Trelleborg developed a bespoke Gina gasket to initially seal against an uneven concrete surface and provide a low reaction force, as well as a relatively large initial compression.



Second chance at increasing accessibility

Second Coen Tunnel Amsterdam, The Netherlands

Problem: A growing population and demand for access to the city of Amsterdam placed existing infrastructure under immense pressure as it competed with new safety regulations and more than 120,000 cars every day.

A second Coen tunnel was constructed containing three fixed lanes and two reversible lanes, to alleviate congestion and improve access to the greater Amsterdam area. The 1,270m tunnel was built in combination with a new highway connection – the Westrandweg – as part of a series of infrastructure enlargement projects, and operates alongside the existing immersed Coen tunnel under the North Sea Canal.

Challenge: There was a higher calculated risk for a sinking ship hence the Gina gasket was required to be designed to face this issue and

the design had to be changed to make a larger gasket. Segment joints with waterstop profiles embedded also had to be enlarged to cope with possible higher deformations.

Solution: As the largest immersed tunnel in the Netherlands, it was essential that each element was securely bonded to protect the tunnel against water ingress. Trelleborg's high-performance seals secured each tunnel element making sure they are watertight and remain functional, even when faced with natural ground movement.



Trelleborg's high-performance seals secured each tunnel element making sure they are watertight and remain functional, even when faced with natural ground movement.



Reducing congestion, sealing safety

Midtown Tunnel Hampton Roads, USA

Problem: Congestion is a growing concern in nearly all major cities, but in Portsmouth, Virginia, this was even more problematic.

Located across the Elizabeth River from Norfolk – the site of the largest US Navy base – the pre-existing Midtown tunnel became a constant gridlock of traffic, carrying a million vehicles per month. When military personnel needed to reach their naval base, the volume of traffic had the potential to cause critical delays. An innovative solution was needed to relieve bidirectional traffic and, above all, promote safety.

Challenge: Hydrostatic loads and movements between the tunnel ends, caused by soil settlement, creep of concrete, temperature effects and earthquakes.

The tunnel had to be built without interference to the ship movements so no delay in delivery of our gaskets was allowed.

Solution: Trelleborg assisted with the creation of a second midtown tunnel that sits parallel to the existing tunnel, which aimed to improve travel times and prevent water ingress from the Elizabeth River.

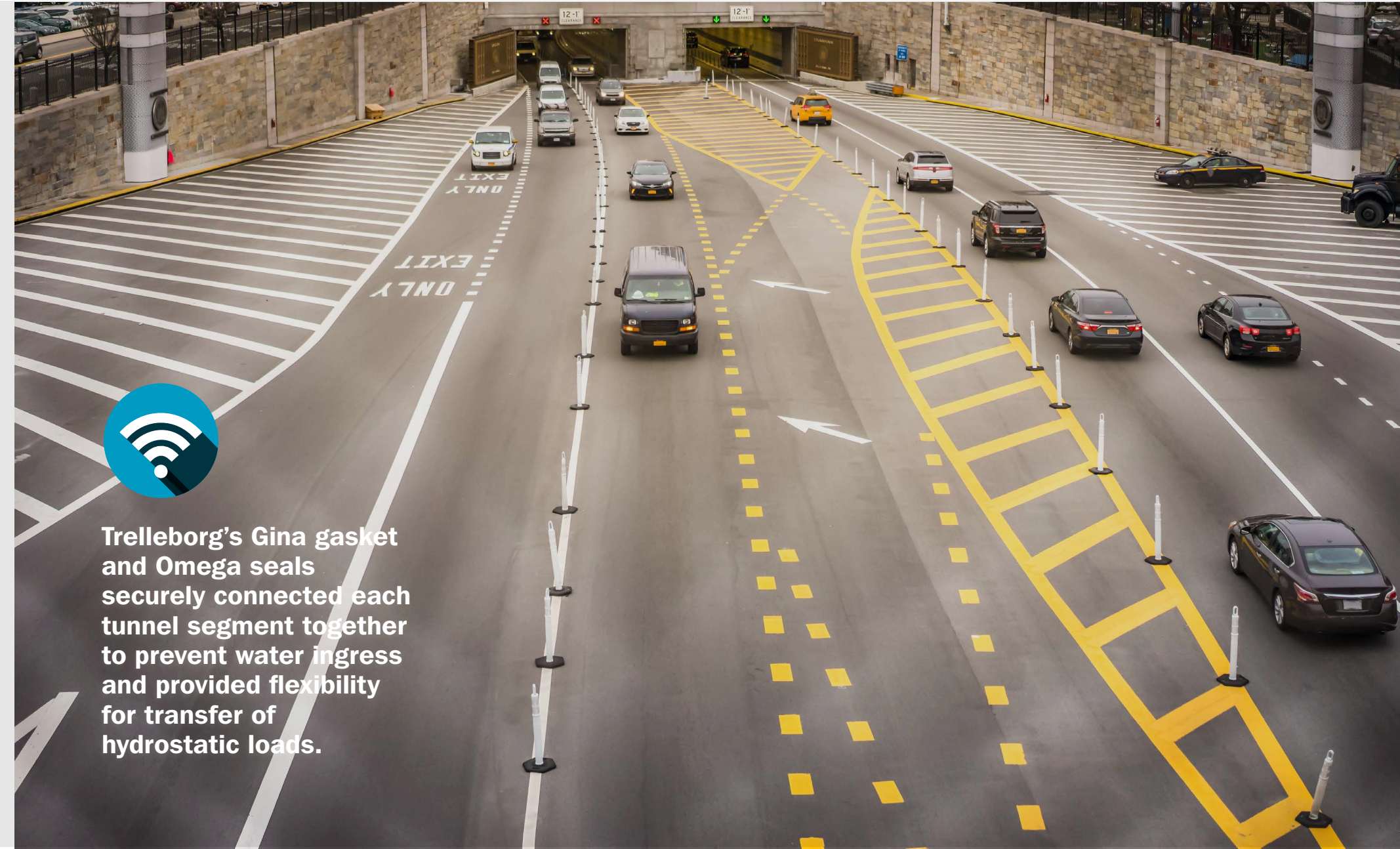
The 1,280m immersed tunnel consisted of 11 rectangular concrete tunnel elements, each of which was fitted with Trelleborg's Gina gaskets and Omega seals to prevent water ingress.

The Gina gasket is made from natural rubber, connecting each segment together, and the

Omega seal consists of multiple layers of styrene butadiene rubber and nylon inlayers to enhance durability and keep the tunnel watertight. Combining the two seals enables the transfer of hydrostatic loads and movements between the tunnel ends, caused by soil settlement, creep of concrete and temperature effects.



Trelleborg's Gina gasket and Omega seals securely connected each tunnel segment together to prevent water ingress and provided flexibility for transfer of hydrostatic loads.



A first for Mexico

Coatzacoalcos Tunnel Coatzacoalcos, Mexico

Problem: The development of industrial complexes on the east of the Coatzacoalcos River meant that the existing bridge with two lanes and a single track was not sufficient for the sheer volume of traffic traveling through it. With more than 18,000 vehicles and 8,000 pedestrians crossing the river between Coatzacoalcos and Allende every day, it was essential that a new route was developed to reduce congestion and improve connections between the cities.

Challenge: Gina gaskets featuring the largest cross sections ever had to be produced, which created logistical challenges. The larger cross sections were required to provide enough resilience of the seal during a possible earthquake.

Solution: At 1.1km long and 35 meters underwater, the Coatzacoalcos tunnel was the first-ever immersed tunnel in Latin America. It was built using an immersion technique, where each element is prefabricated in a dry dock before being towed to the tunnel site, to minimize the impact on the environment during construction.

Five monolithic elements were used to build the tunnel, reducing the risk of damage and leakage caused by earthquakes. Finding seals that would be flexible enough to work with the monolithic elements and protect the tunnel from water ingress was critical. Trelleborg developed a new Gina gasket with more deformation capacity to allow for unrestricted movement and secure connections between each element, while simultaneously protecting against high pressures of water and seismic movements.



Trelleborg developed a new Gina gasket with more deformation capacity to provide unrestricted movement and secure connections between each element.

Underwater connection in Stockholm

Söderström Tunnel Stockholm, Sweden

Problem: The Citybanan project included a new 6km-long, two-track tunnel connecting Riddarholmen and Söderström, designed to reduce congestion of the S-Bahn transit system where more than 350 trains pass through each day. The main element of this structure was a 340m immersed underwater tunnel, connecting the rock tunnels at either side of Lake Ridderfädem.

Challenge: The tunnel is built out of steel caissons and the Gina gasket was only used as a temporary measure to keep the tunnel watertight until the tunnel elements were welded together. Uneven surfaces and alignment had to be compensated by the Gina gasket.

Solution: The immersed tunnel was separated into three prefabricated, 100m twin-track

elements, including two short cut and cover tunnels and one joint house. To avoid contact with the soft seabed, and due to the limited water depth, the tunnel was constructed as a sandwich tunnel with a concrete and double steel shell, and placed on three pile groups, partly above the seabed. A special configuration was needed for the Omega seal to be located in the joint house (where the tunnel reaches the shore). A double Omega seal was applied for safety and had to be installed in a tight space.

Trelleborg supplied seals to connect each of the three tunnel elements using a prestress method. This unique application provided protection of the tunnel components from water ingress, while ensuring the seals were flexible enough to allow for substantial movement without damaging the structure.



Trelleborg supplied seals to connect each tunnel element using a unique prestress method, protecting the tunnel from water ingress.

The world's longest link

Hong Kong-Zhuhai-Macau Bridge Hong Kong, China

Problem: To cut travel time and enhance economic integration between Hong Kong, Macau and Zhuhai (HKMZ), construction began on one of the most technically complex projects ever. Central to creating the link between the three locations was the world's longest deepwater immersed tunnel at almost 6km in length, which would allow for flow of road traffic.

Challenge: As a combination of bridge, tunnel and artificial island, the 49.9km HZMB is a mega-link between Hong Kong, Zhuhai and Macau.

The island and tunnel project is a critical part of the overall construction work, and involves the most difficult to construct immersed tunnel in the world.

The project is sophisticated and risky - it required highly specific technical standards.

Watertightness is key to the island and tunnel project of the HZMB. Trelleborg will ensure that 33 tunnel sections remain safe at deep-sea depths of up to 40 meters.

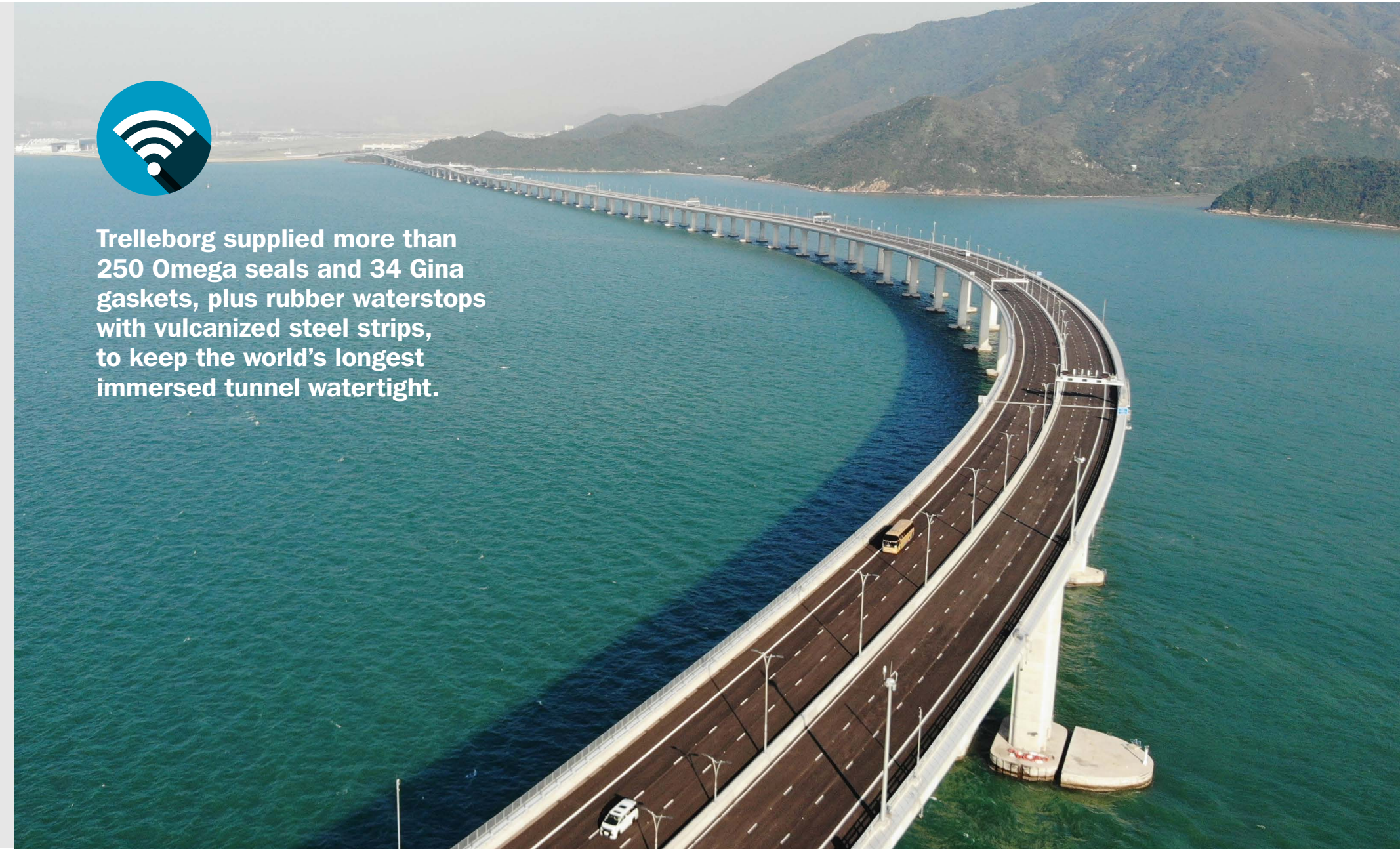
The implementation of the closure joint was the biggest challenge as it was unique in its kind and never built this way before. A lot of engineering assistance was required to ensure that the Trelleborg profiles matched the detailed requirements.

Solution: With an expected lifespan of at least 120 years, the HZMB immersed tunnel needed to remain resilient and watertight for

years to come. The sealing systems involved more than 250 Omega seals of varying sizes, as well as 34 Gina gaskets spanning 90 meters in circumference. Rubber waterstops with vulcanized steel strips were also manufactured to make the concrete sections watertight, even when faced with ground movement.



Trelleborg supplied more than 250 Omega seals and 34 Gina gaskets, plus rubber waterstops with vulcanized steel strips, to keep the world's longest immersed tunnel watertight.



Immersed in rail

Sha Tin-Central Immersed Tunnel Hong Kong, China

Problem: Ever-growing demand for travel to the mainland of Hong Kong called for immediate action to allow individuals to traverse easily. So, when construction began on the Sha Tin to Central Link tunnel, carrying twin rail tracks to connect Kowloon to Hong Kong Island, there was only one supplier in mind to seal the immersed tube tunnel spanning 1.3km of the Victoria Harbour – Trelleborg.

Challenge: The biggest challenge was that the fact the Gina gaskets were mounted while the tunnel elements remained floating in Hong Kong harbour for a period of 6 months. The Gina gaskets had to be protected against marine growth and therefore Trelleborg implemented a solution with an anti-fouling coating to mitigate marine growth and prevent extensive cleaning prior immersion by divers.

Solution: The project consisted of 11 concrete elements of approximately 160 meters each, which needed to be towed to the construction site by sea. Trelleborg's Gina gaskets, supplied as closed rectangular frames, alongside the Omega seals, were used to seamlessly connect each of the concrete elements. The advanced design of the seals and gaskets means they have an outstanding ability to withstand seismic activity and absorb movement.

As the Gina gasket is softer, it could be closed more easily upon initial compression. This means that installers could deploy a lighter jacking force to seal the deeper joints, reducing the time it takes to, and the overall cost of, closing the seals.

Acting as the primary seal, the Gina gasket prevents water ingress by withstanding extreme water pressure, while the Omega seal serves as the secondary safety seal that can endure even the most severe ground movements.



Trelleborg's Gina gaskets were supplied as closed rectangular frames, alongside Omega seals, to seamlessly connect each concrete tunnel element and protect against seismic activity.

A port under pressure

Marieholm Tunnel Gothenburg, Sweden

Problem: The port of Gothenburg, Sweden, is the largest port in the Nordic region, with around 11,000 vessels visiting the port each year. Coupled with more than half a million residents in its urban area, Gothenburg is quickly becoming one of the fastest growing regions in Northern Europe. The existing river crossings were becoming vulnerable and overloaded by road traffic, and the amount of frail height was increasing rapidly, so a modern solution was needed to relieve congestion.

Challenge: Technical challenges to cope with extreme movements due to soft soil and therefore higher settlement.

Solution: Trelleborg assisted with the construction of the Marieholm Tunnel, which acts as an additional crossing over the Göta

Älv. Opened in December 2020, the Marieholm tunnel will feed all major motorways in Gothenburg and reduce disruption on local roads.

The outer concrete structure of the tunnel is 31 meters wide and 9.5 meters high, so there was a need for high-quality seals that could cater for these requirements at a depth of 20 meters. The proven high-stability, flexibility and behavior of Trelleborg's tunnel seals made them the perfect match for the development of the 500-meter long Marieholm Tunnel.

The Gina gaskets and Omega seals are used between the sectional elements of the immersed tunnel, alongside waterstops at the construction joints which are engineered to ensure watertightness.



Gina gaskets and Omega seals were used for the sectional tunnel elements, alongside water stops at the construction joints which are engineered to ensure watertightness.





Trelleborg is a world leader in engineered polymer solutions that seal, damp and protect critical applications in demanding environments. Its innovative solutions accelerate performance for customers in a sustainable way.

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