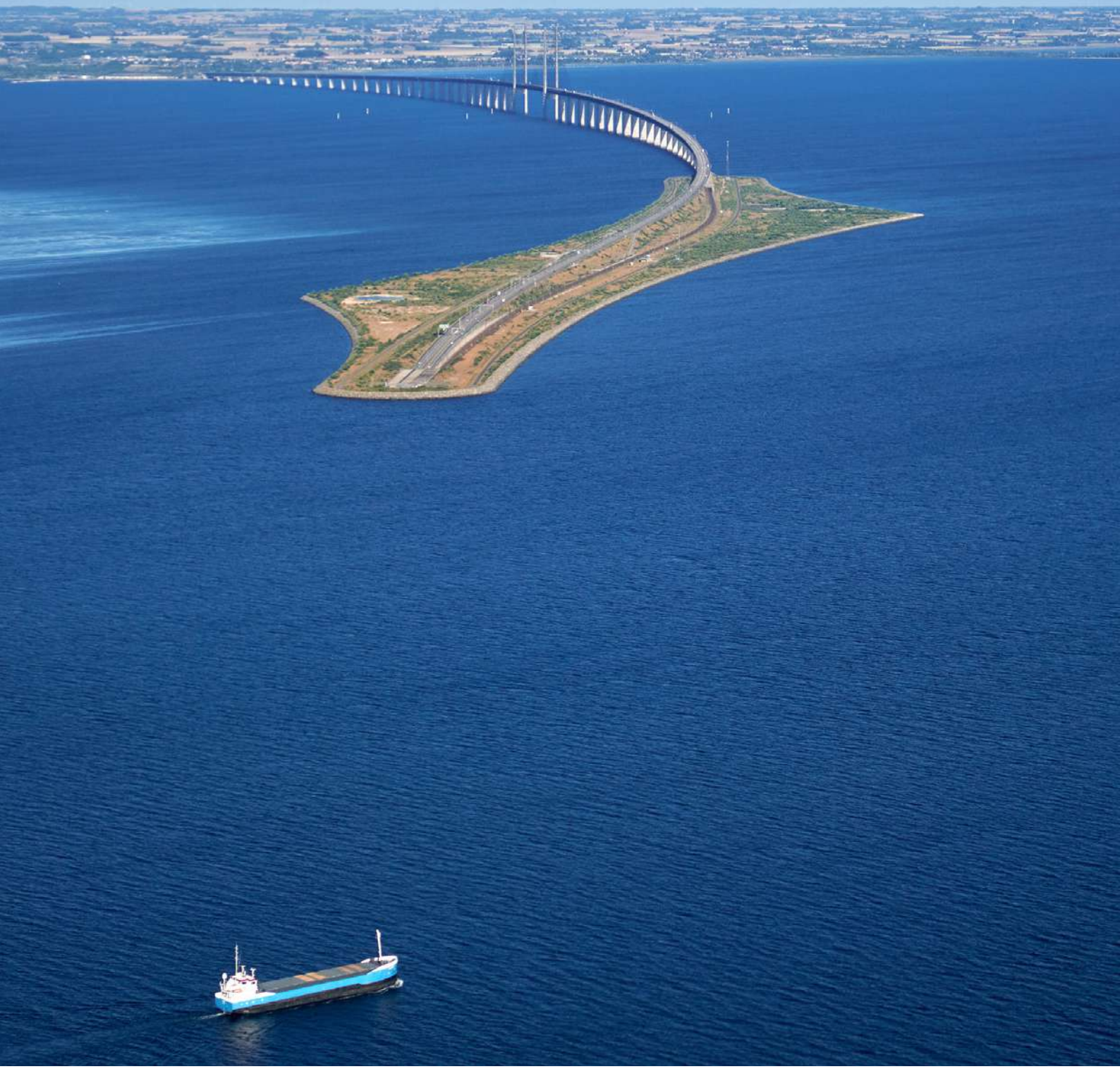
Immersed tunnel sealing systems

PRECISION-ENGINEERED SOLUTIONS FOR CRITICAL INFRASTRUCTURE



SCAN FOR MORE INFO

At Trelleborg, we are committed to designing solutions that quite literally, ‘seal the deal!’ With an undisputed lifespan of 120 years, our sealing systems are engineered to stand the test of time, supporting the integrity of immersed tunnels for generations.

Smarter, reliable and sustainable sealing

Immersed tunnels play a vital role in connecting communities, supporting economic growth, and enabling efficient, sustainable transport.

As climate change accelerates and urban populations expand, the demands on critical infrastructure continue to rise. Trelleborg Marine and Infrastructure has been a trusted global player in tunnel seals for more than six decades, delivering proven systems that ensure long-term durability, flexibility, and watertight performance even under extreme conditions.

Our engineered Gina gaskets, Omega seals, and advanced waterstop technologies protect immersed tunnel structures from water ingress, seismic movement, and hydrostatic pressure. With an expected lifespan of 120 years or more, these solutions safeguard the integrity of tunnels worldwide.

Backed by unrivalled engineering expertise and a legacy of successful high-profile projects, Trelleborg continues to set industry benchmarks in safety, performance, and resilience. This brochure highlights our most iconic references and showcases how our innovative sealing systems enable the world's most ambitious underwater infrastructure.

Contents

Sealing Systems for Immersed Tunnels

Meeting the challenges of immersed tunnel performance

In the context of Trelleborg's immersed tunnel sealing systems, the challenges addressed span from macro-environmental and societal pressures to highly specific technical and logistical constraints unique to each project. The overarching objective is to ensure long-term structural integrity and watertight performance for a service life of up to 120 years.

GLOBAL AND ENVIRONMENTAL CHALLENGES

Trelleborg solutions are engineered to withstand external forces that conventional systems can no longer manage:

Urbanization & Climate Pressure: Rapid population growth in major cities places mounting stress on existing infrastructure. Rising sea levels and climate-driven flood risks require tunnel structures capable of resisting extreme hydrostatic loads.

Sustainability Requirements: Immersed tunnels support more sustainable mobility by reducing travel lengths and minimizing impact on natural ecosystems.

TECHNICAL AND GEOPHYSICAL CHALLENGES

Each tunnel presents distinct environmental conditions requiring customized engineering:

Hydrostatic Pressure & Depth: Hydrostatic pressure increases significantly with depth, placing constant long-term stress on immersed tunnel sealing systems. To maintain watertight integrity over decades, seals must perform reliably under sustained extreme pressure.

Seismic Activity: In high-risk regions such as the so-called "Ring of Fire" that spans the Americas and Asia, tunnel seals must provide enhanced deformation capability to absorb seismic movement while maintaining full watertightness.

Soft-Soil Instability: Soft-soil conditions can cause significant ground settlement, placing continuous movement demands. To maintain long-term watertight integrity, seals must be able to accommodate differential movement without loss of performance.

Structural Behavior: Over an immersed tunnel's long service life, concrete creep, temperature changes, and differential ground movement cause ongoing structural deformation. Sealing systems must be designed to accommodate these effects while maintaining watertight integrity over decades of operation.

LOGISTICAL AND INSTALLATION CHALLENGES:
Project constraints often extend beyond engineering to complex on-site conditions:

Operational Interference: Operational constraints can shape immersed tunnel installation, particularly where construction must coexist with active navigation routes.

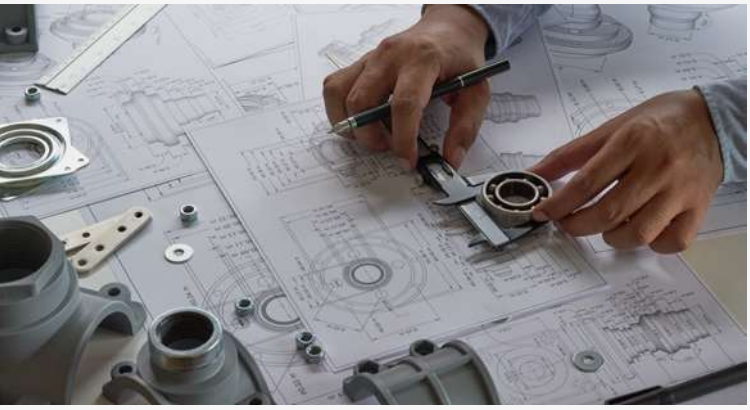
Irregular Surfaces: Irregular concrete surfaces can compromise initial sealing during immersed tunnel installation, requiring solutions that adapt immediately to uneven interfaces.

SPECIFIC RISK SCENARIOS:

Unique Cases: Unique risk scenarios can influence immersed tunnel system design, requiring solutions that go beyond standard loading assumptions. Where the risk of external impact or anchor drag exists, sealing systems must withstand extreme deformation without loss of integrity.

Our core capabilities

Addressing the complex environmental, technical, and operational challenges of immersed tunnels requires more than individual products—it demands integrated expertise applied across the full project lifecycle. Trelleborg's core capabilities bring together design engineering, product excellence, and on-site field service to manage risk, ensure watertight integrity, and deliver reliable performance from initial concept through long-term operation.



DESIGN ENGINEERING

Our global engineering team supports customers in identifying and designing the optimal solution for each project, providing technical support, advanced design capabilities, and finite element analysis tailored to specific project requirements.

PRODUCT EXCELLENCE

Designed and manufactured to last for over 120 years, our Gina gaskets, Omega seals and Waterstops represents the most optimal solution to make your infrastructure watertight.

ON-SITE FIELD SERVICE

From expert installation support to field testing, inspection and maintenance, our skilled field service team ensures continuous watertight performance across the full tunnel lifecycle.

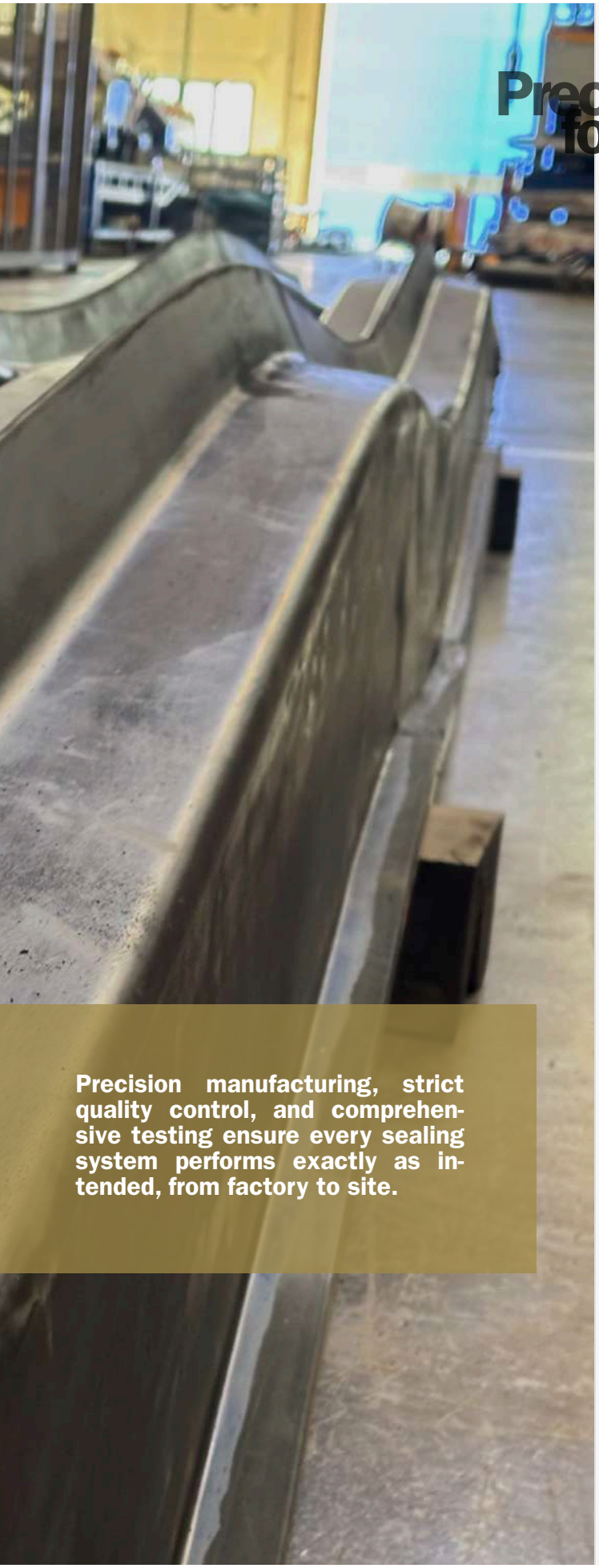
Expert engineering for complex challenges

Tunnel-sealing is a mission-critical discipline where precision is non-negotiable. That's why infrastructure owners and contractors rely on Trelleborg's specialized sealing systems and engineering competence to secure durable, long-term watertight performance in the world's most demanding environments.

PROACTIVE APPROACH, PROVEN RESULTS

Our global engineering team plays a hands-on role from the very beginning of every immersed-tunnel project. Our experts engage directly with all stakeholders at the earliest stages to ensure every technical requirement is accurately understood and fully reflected in the project specifications.

Beyond defining requirements, our engineers develop the complete concept and design of the sealing system. Their mission goes far beyond supplying components—they provide the technical guidance and assurance needed to help immersed tunnels maintain reliable watertight performance throughout their intended service life, supported by sealing systems engineered to last 120 years.



Precision manufacturing, strict quality control, and comprehensive testing ensure every sealing system performs exactly as intended, from factory to site.

Precision-built products for long-term performance

IN-HOUSE PRODUCTION FOR QUALITY ASSURANCE

Designed and manufactured in-house, Trelleborg's flagship sealing systems, including Gina gaskets, Omega seals, and Waterstops, set the benchmark for long-term watertight performance in immersed tunnels. Continuous innovation in polymer engineering, materials, and design enables these solutions to withstand extreme loads, movement, and environmental conditions, supporting a design life of 120 years. By controlling the full manufacturing process, Trelleborg ensures precision, consistency, and uncompromising quality in every product delivered.

Each sealing system undergoes rigorous testing and inspection after production, with additional verification during installation on site to ensure performance meets project-specific requirements. This end-to-end quality assurance approach minimizes risk and gives customers confidence that only validated, proven solutions are installed. Trusted on immersed tunnel projects worldwide, Trelleborg sealing systems are supported by an extensive global reference list and a long track record of reliable, failure-free performance in the most demanding applications.

On-site expertise for new and aging immersed tunnels

At Trelleborg, we ensure not only that new immersed tunnels are watertight, but that aging tunnels remain safe and protected. As more early-generation tunnels pass the 50-year mark, their exposure to changing water pressure, geologic settlement, and long-term traffic loads increases.

Our expertise in inspection and maintenance helps owners address these evolving forces, keeping their tunnels performing and even extending the lifetime expectancy of the tunnel.

We inspect

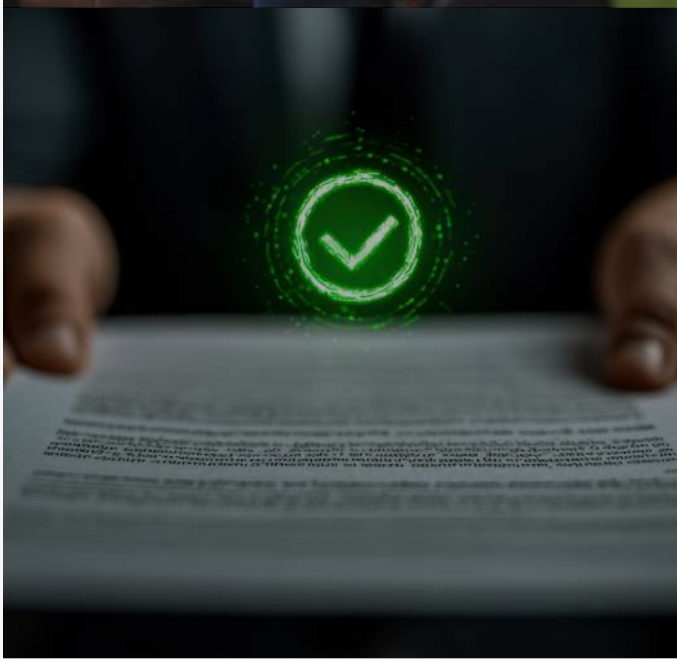
- **We evaluate the condition of the joint/seal and consequent watertightness.**
- **We advise when maintenance or conservation work is required, whether immidiate or in the future.**

We service

- **We carry out seal conservation or replacement works.**
- **We perform clamping system conservation or replacement works.**

We validate

- **We document our services.**
- **We validate the inspection and maintenance work done.**

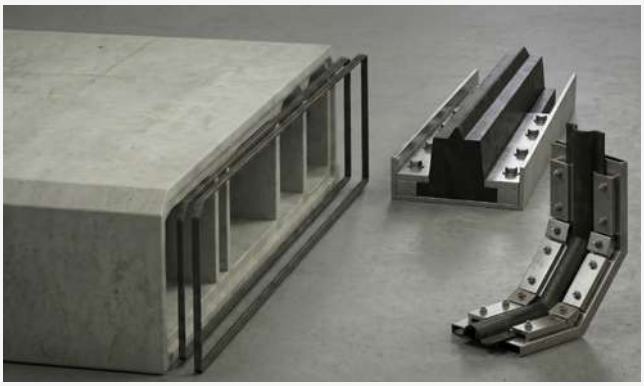


What we do:
Securing long-term watertight performance

Proven across critical tunnel applications

IMMERSION JOINTS

Immersion joints form the critical interfaces between immersed tunnel elements and are required to maintain long-term watertight performance. This is achieved through an integrated system combining a primary Gina compression gasket, a secondary Omega seal to absorb movement, and precision-engineered clamping strips, working together to reliably prevent water ingress under demanding hydrostatic, geotechnical, and seismic conditions.



SEGMENT JOINTS

Segment joints connect tunnel segments and must accommodate movement while remaining watertight over the long term. This is achieved using Waterstops, Calamity gaskets, and high-performance ACME and AM seals, designed to withstand pressure and structural movement.

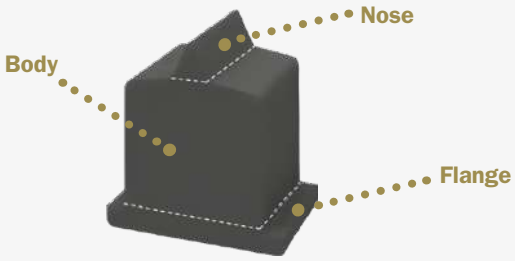
CLOSURE JOINTS AND TEMPORARY WORKS

Bulkhead seals, closure joint seals, and pin-and-catch systems play a vital supporting role in ensuring the successful construction and long-term integrity of immersed tunnels. Bulkhead seals temporarily prevent water ingress during immersion, closure joints secure the final connection to complete the tunnel, and pin-and-catch systems guide and lock elements into precise alignment. Together, these engineered solutions support safe installation, controlled connection, and reliable performance under demanding conditions.

Gina gasket and Omega seal, where technology meets critical protection

PRIMARY SEAL: THE GINA GASKET

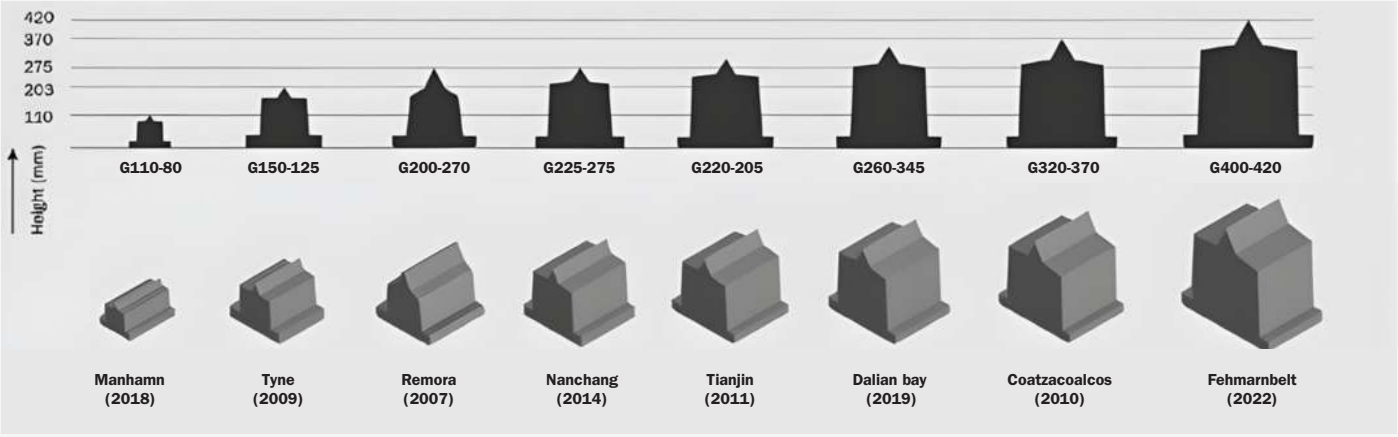
The Gina gasket is the primary watertight seal between immersed tunnel elements, engineered to prevent water ingress under extreme hydrostatic pressure. Custom-designed for each project, this high-performance rubber profile compresses during element connection to form a robust, reliable seal, delivering watertight integrity for a certified design life of 120 years.



KEY FEATURES

- **Made from high-quality natural rubber**
- **120+ year design life (3rd party tested)**
- **Absorbs hydrostatic loads, adapts to surface irregularities, and withstands environmental factors such as temperature fluctuations**
- **Fully continuous design, no weak points, ensuring long-term reliability**
- **Engineered compound: soft nose for initial low-compression seal, project-specific body for ideal performance, and hard flange for secure fixation with Trelleborg clamping strips**

CONTINUOUS INNOVATION



The Gina gasket has steadily evolved from the early immersed-tunnel applications of the 1960s, such as the Rotterdam Metro project, into a far more advanced sealing element used in today's mega-projects.

Tunnels are getting longer, wider and are being installed in deeper waters, often in seismic areas. These changes are also reflected in the evolution of the Gina gasket.

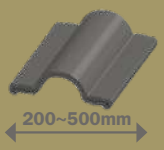
- Bigger sizes
- Bigger deformation capacity
- Bigger material sophistication

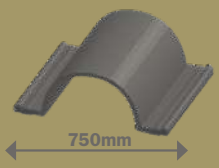
SECONDARY SEAL: THE OMEGA SEAL

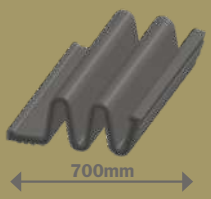
The Omega seal is a reinforced engineered rubber sealing system designed to maintain watertight integrity in joints that can experience movement, such as immersed tunnel element connections. It acts as the secondary seal, installed inside the joint after the Gina gasket has created the initial seal.

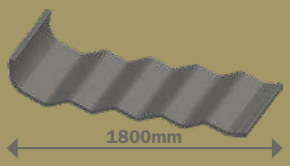
KEY FEATURES

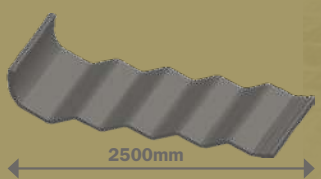
- **Designed to withstand high pressure and movements**
- **120+ year design life (3rd party tested)**
- **Suitable for a variety of applications**
- **Replaceable during refurbishment**
- **Custom engineering options, including water pressure test valves**











KEY CHARACTERISTICS

- **Engineered versatility:** suitable for both new immersed-tunnel construction and retrofit projects.
- **Precision-engineered clamping system:** bespoke seamless integration into the host structure.
- **Tunable performance:** configuration based on geometry, strength of integrated reinforcement plies, and the differential water pressure it must withstand.

We evaluate all performance requirements, environmental conditions, and functional demands to confirm that the seal will reliably achieve its intended purpose and comply with specifications.

Strong clamping for stronger tunnel performance

THE CRITICAL ROLE OF FIXING SYSTEMS

Effective tunnel sealing depends on more than seal design alone. Without a reliable fixing system, even the most advanced gaskets can underperform. Inadequate clamping can lead to uneven compression, reduced watertightness, premature wear, and increased maintenance over time, creating risk for long-term tunnel performance.

Trelleborg addresses this challenge with a well- engineered fixing system designed as an integral part of the solution. Our steel clamping strips are bolted along the sides of the seal, securing it firmly in place and ensuring consistent load distribution. By eliminating steel embedded within the rubber, our design avoids internal corrosion and supports long-term durability, even under demanding conditions.

The result is reliable watertight performance, simplified installation, and reduced maintenance over the tunnel's service life. With less fixation material and a more efficient installatino process, customers benefit from a cos-effective solution that delivers durability, performance, and peace of mind.

Engineered to hold firm under pressure

Gina gasket with clamping strips

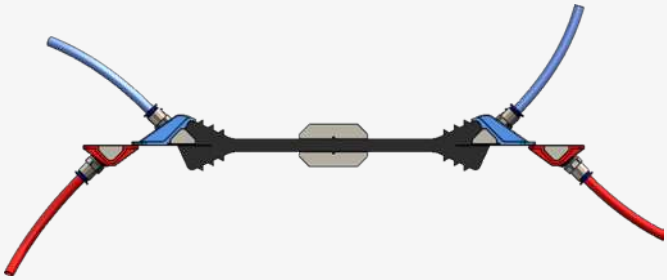
Omega seal with clamping strips

Waterstop & other segment joint seals for uncompromised protection

SEGMENT JOINT SEALS: THE WATERSTOP

Trelleborg waterstops are designed for watertight concrete segment joints subject to movement.

Cast directly into the concrete, these waterstops provide a secure, leak-proof seal, accomodating joint expansion, contraction, or settlement penetration throughout their 120-year design life.

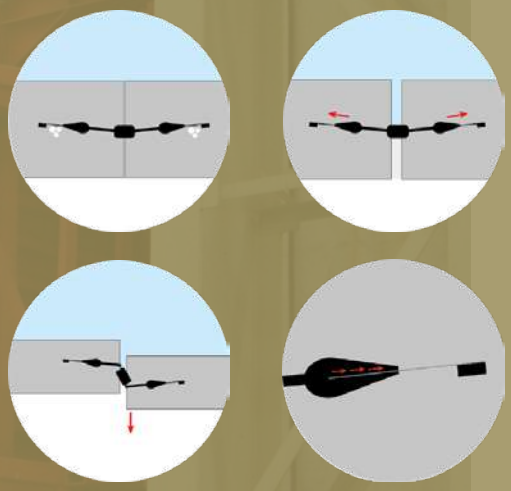


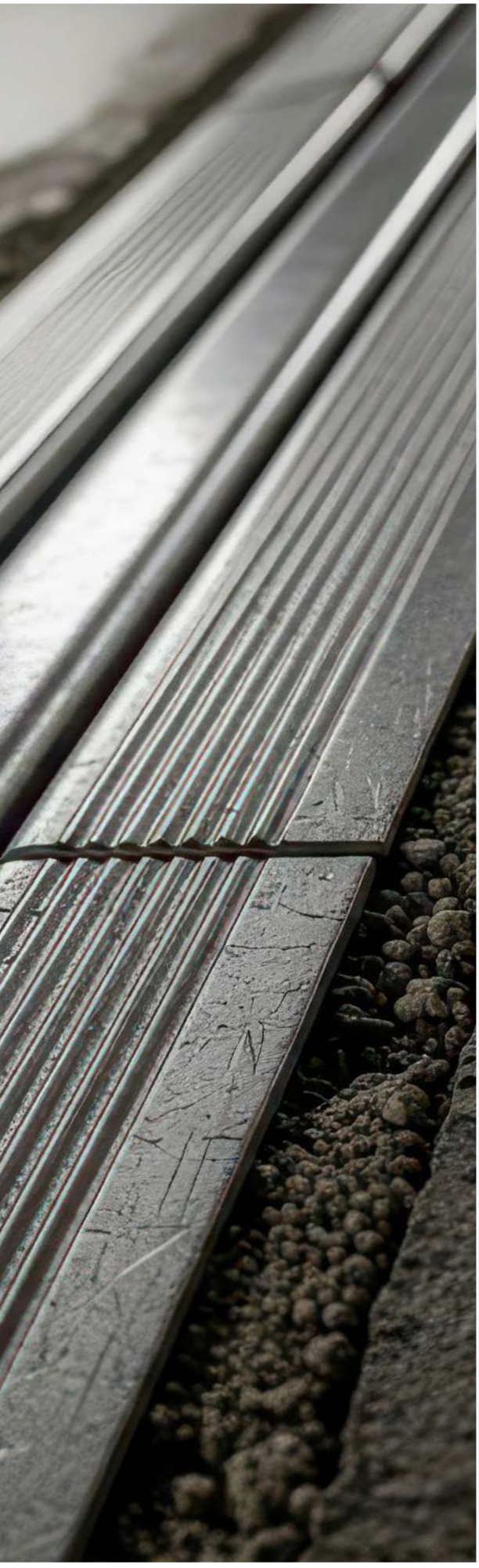
KEY FEATURES

- **Best in class performance**
- **120+ year design life (3rd party tested)**
- **Maintenance free**
- **Vulcanized joining on site**
- **Innovative, flexible, double-sided injection system**
- **Epoxy injection distance of 6 meters**

KEY CHARACTERISTICS

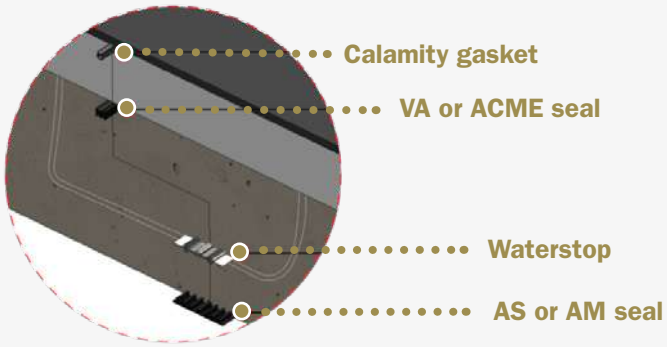
- **Ease of installation:** flexible plug-and-play hoses for reliable easy installation.
- **Tested for concrete expansion & shrinkage:** made to withstand elongation.
- **Large settlement proof:** resistant to environment changes.

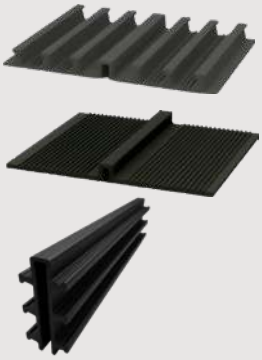




OTHER SEGMENT JOINT SEALS

Trelleborg segment seals are designed and manufactured to guarantee the essential functionality of segment joints while ensuring the tunnel's integrity and flexibility.



CALAMITY GASKET	VA & ACME SEALS	AM, AS & FAE SEALS
This seal is installed at the tunnel floor section and serves to protect the sealing systems located beneath it from calamity events, such as oil spillages. It preserves joint integrity and sealing performance.	The VA and ACME seal product lines are designed to create a durable barrier that prevents the ingress of dirt, soil, and debris, thereby preserving joint integrity under long-term movement.	These seals are applied at the floor, walls and roof sections of tunnel structures. The cast-in installation protects the external joint by forming a continuous barrier against water ingress, mud, dirt, and other external substances.
		

Where tunnels come together and stay watertight

CLOSURE JOINT

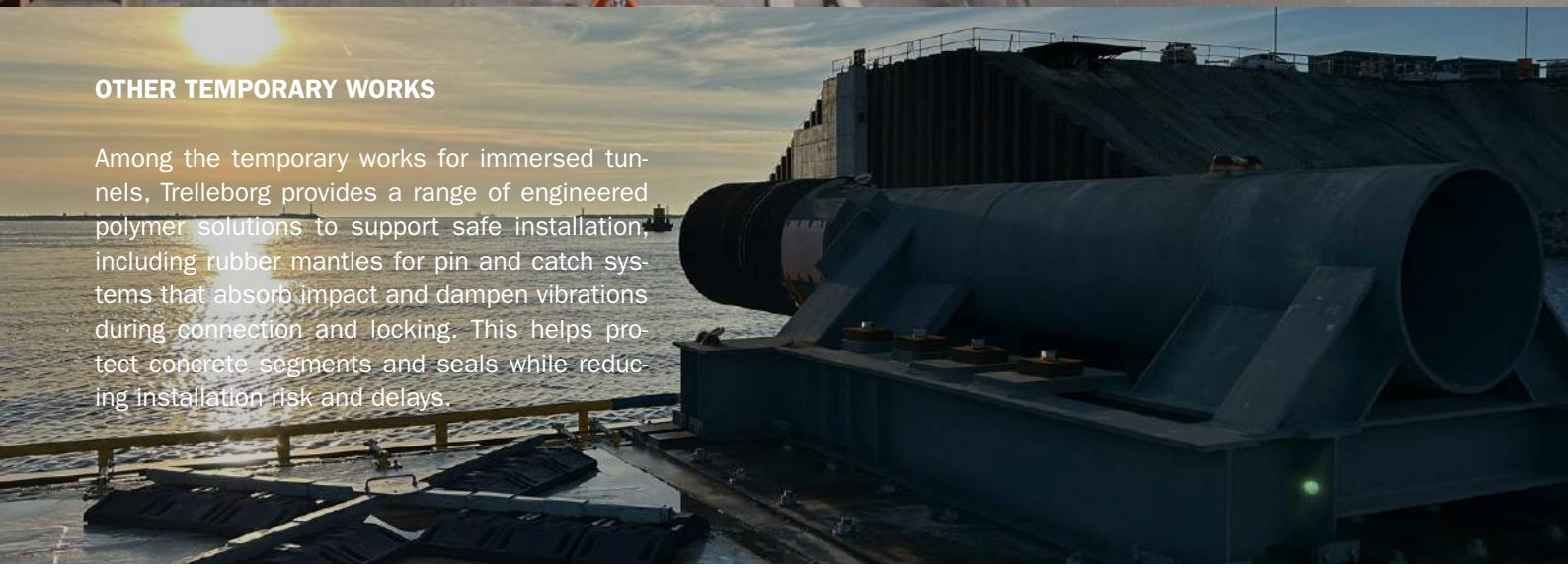
A closure joint seals the gap between the last immersed tunnel element and the rest of the tunnel. It allows the closure of the tunnel line after all tunnel elements have been immersed and connected.

This requires specifically engineered primary and secondary seals, which our team has the knowledge, capabilities and experience to produce and install.

BULKHEAD SEALS

Bulkhead seals prevent water from entering tunnel elements during the immersion process. After the activation of the immersion joints, these seals, together with the bulkhead panels, are removed and reused to make the other segment joints watertight during immersion.

At Trelleborg, we don't just provide the membrane frames but also the clamping system for fixation. We design and manufacture these steel components to create a fully integrated water defence system.



OTHER TEMPORARY WORKS

Among the temporary works for immersed tunnels, Trelleborg provides a range of engineered polymer solutions to support safe installation, including rubber mantles for pin and catch systems that absorb impact and dampen vibrations during connection and locking. This helps protect concrete segments and seals while reducing installation risk and delays.

Manufacturing & quality control

IN-HOUSE MANUFACTURING

By keeping our core production process under control, we maintain the strictest quality standards at every stage, from material selection to final testing.

This approach allows us to optimize manufacturing processes to meet the specific needs of our customers, ensuring that each seal is tailored to deliver exceptional performance in its intended application. We implement continuous improvements, adapt quickly to unique project requirements, and uphold our commitment to delivering durable, high-quality solutions that exceed industry standards.

QUALITY CONTROL

At Trelleborg, we implement a comprehensive range of quality control measures throughout the production process. Below is an overview of the key quality control measures we perform.

Material validation: Extensive testing of compound materials

Batch control: Physical testing of compound batch properties

Load deflection test: to validate product performance

Segment stamp test: 100% to verify quality

Corner stamp test: 100% to verify quality Joint stamp test: 100% to verify quality

Visual and dimensional inspection on full frame to ensure quality

PRODUCTION PROCESS OF THE GINA GASKET

The production process of the Gina gasket is a meticulous and highly controlled operation.

It begins with the preforming phase, where the different rubber compounds for the nose, body, and flange are extruded through precision-engineered molds to create the individual components of the gasket.

Following this, the process moves to the Segment Vulcanization phase, a critical step that can take up to 14 hours. During this phase, the rubber segments are vulcanized to achieve the desired strength, elasticity, and durability.

Once the segments are prepared, the vulcanization of the joining takes place, seamlessly bonding the components together to create a continuous, watertight gasket.

Finally, after meticulous quality control, the completed gasket is carefully packaged by folding it into 40ft open containers, ensuring safe transportation while maintaining its structural integrity.

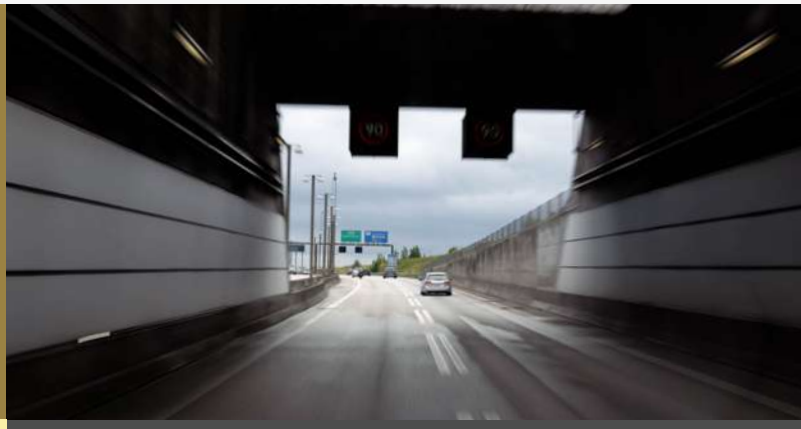
This rigorous production process guarantees that every Gina gasket meets the highest standards of quality and reliability, ready to perform in the most demanding applications.

Proven in practice: a selection of recent immersed tunnels

Øresund LINK (Denmark - Sweden)

Trelleborg supplied a specially designed combination of sealing systems to seal tunnel sections, as part of the 16km long bridge/tunnel project between Denmark and Sweden.

Operational since 2000



Second Coen Tunnel (Amsterdam, The Netherlands)

For the 1,270m immersed tunnel aimed at relieving congestion in Amsterdam, Trelleborg's high-performance seals secured each tunnel element and segment, protecting against water ingress.

Operational since 2013

Midtown Tunnel (Hampton Roads, USA)

Trelleborg supplied its Gina gasket and Omega seals to securely connect the 11 tunnel elements for the 1,280m immersed tunnel near the site of the largest US naval base in Portsmouth, Virginia.

Operational since 2016

Coatzacoalcos Tunnel (Coatzacoalcos, Mexico)

For the first-ever immersed tunnel in Latin America, Trelleborg developed a new Gina gasket with more deformation capacity, providing secure connections for each tunnel element.

Operational since 2017

Söderström Tunnel (Stockholm, Sweden)

Trelleborg supplied seals using a unique prestress method for the 6km-long, two-track tunnel connecting Riddarholmen and Söderström, ensuring the tunnel components were watertight.

Operational since 2017

Hong Kong-Zhuhai-Macau Bridge (Hong Kong, China)

34 of Trelleborg's Gina gaskets and over 250 Omega seals were used to seal the tunnel elements for one of the world's longest deepwater immersed tunnel.

Operational since 2019

Sha Tin-Central Immersed Tunnel (Hong Kong, China)

For the Sha Tin to Central Link tunnel, Trelleborg's Gina gaskets were supplied as closed rectangular frames, as well as Omega seals, to secure the 11 concrete elements and ensure they were watertight.

Operational since 2022

Marieholm Tunnel (Gothenburg, Sweden)

Trelleborg's Gina gaskets and Omega seals were used between the sectional elements of the immersed Marieholm tunnel, alongside waterstops at the construction joints, to ensure watertightness.

Operational since 2020

Fehmarnbelt Fixed Link (Germany - Denmark)

For what will become the longest immersed tunnel in the world, Trelleborg has designed the biggest Gina gasket of its portfolio. This, together with its Omega seals and the innovative injectable waterstops, will contribute to making this project a milestone in engineering.

Complete in 2029

Hippolyte la Fontaine tunnel (Montreal, Canada)

Trelleborg's Omega seals were instrumental in ensuring this tunnel remains functional for years to come. Our field service team performed thorough inspections and reinforcement work to maintain the watertightness of this critical infrastructure.

Inspected and serviced in 2026

Rotterdam Metro Tunnel (Rotterdam, The Netherlands)

For this immersed tunnel dating back to the 1960s, Trelleborg observed degradation of concrete condition and advanced sand pressure compromising the efficacy of the seals. Our engineering and field service teams worked together to remedy the joints with bespoke innovative solutions.

Inspected and serviced in 2015

SCAN TO READ OUR REFERENCE LIST

DISCLAIMER

Trelleborg AB has made every effort to ensure that the technical specifications and product descriptions in this brochure are correct.

The responsibility or liability for errors and omissions cannot be accepted for any reason whatsoever. Customers are advised to request a detailed specification and certified drawing prior to construction and manufacture. In the interests of improving the quality and performance of our products and systems, we reserve the right to make specification changes without prior notice. All dimensions, material properties and performance values quoted are subject to normal production and testing tolerances.

This brochure supersedes the information provided in all previous editions. If in doubt, please check with Trelleborg Marine and Infrastructure.

At Trelleborg, sustainability is at the core of everything we do. We are helping to decarbonize the maritime industry by providing smart and technologically advanced solutions like AutoMoor, which result in reduced emissions and increased efficiencies, further benefiting our customers. Our sustainability initiatives are not just an afterthought, but the very foundation on which we build our success.

SCAN FOR MORE INFO

TRELLEBORG

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.

Trelleborg Marine and Infrastructure is a leading provider of premium solutions for critical marine, port, and built infrastructure applications. Its innovative polymer and smart technology solutions enhance operational efficiency, safety, and sustainability.

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