

# Fehmarnbelt Tunnel Construction Underway

An update on the progress at Europe's largest construction site

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Anyone who has driven from the Netherlands to Scandinavia will recognize the dilemma: either you take the ferry from Germany (Puttgarden on the island of Fehmarn) across the Fehmarnbelt to Denmark (Rødby on the island of Lolland), which will take you across in less than an hour, or you detour 160 km through Jutland and over the Great Belt Bridge. After 2029, this choice might become a lot easier, as the world's longest immersed tunnel will open between Fehmarn and Lolland: the Fehmarnbelt Tunnel. Through this 18-kilometer-long tunnel, you can drive to the other side in just ten minutes, saving about an hour of travel time. Rail transport benefits even more, as the duration of a train journey between Copenhagen and Hamburg will almost halve from 4.5 hours to 2.5 hours. But before that happens, there is still a lot of (civil) work to be done on Northern Europe's largest infrastructure project, with a budget of around €7 billion; and a significant role is played by Dutch engineers and contractors.



Figure 1: Cross-section regular tunnel element (left) and special element (right) (Images: RAT / Schönherr)

## Initiation phase

As early as 1991, Denmark and Sweden expressed their intention to realize a fixed link across the Fehmarnbelt. An agreement between Denmark and Germany followed in 2008. The subsequent design competition in 2011 concluded that an immersed tunnel is the best solution for the intended location. The presence of particularly large boulders in the seabed meant that a bored tunnel was not the preferred option. The main objections to a bridge connection were the presence of important bird migration routes and the lower availability of a bridge compared to a tunnel. After a long permit process, the German supreme court gave the final green light in the autumn of 2018, and realization started in 2019.

## Organization

The project owner and future operator of the tunnel is Femern A/S, a state-owned company which falls under the Danish Ministry of Infrastructure. Femern A/S contracted the joint venture RAT as a consultant, which consists of engineering consultants Rambøll, ARUP and the Dutch Tunnel Engineering Consultants (TEC). The latter, a global leader in the design and maintenance of immersed tunnels, is a permanent partnership between Haskoning and Witteveen+Bos.

## The tunnel

The Fehmarnbelt tunnel consists of two railway bores each with one track, and two road bores, each with two lanes, and an emergency lane. Between the road bores is a central gallery for cables and emergency exits among other things. The 18-kilometer-long immersed tunnel will be constructed from 89 concrete tunnel elements, including 79 standard

tunnel elements and 10 special elements. The standard elements have a length of 217 meters, a height of 8.9 meters and a width of 43 meters, including the lifting corbels which connect to the lifting hooks of the immersion pontoon. Each element weighs 73,000 tonnes. The special elements, which are placed in between every eight standard elements, have a different design with a length of 'only' 38 meters. The special elements are about three meters higher, providing space for an extra level to accommodate technical installations and a pump sump (see Figure 1). To access this lower level without causing any disruption to traffic, the western road bore is provided with a parking bay. This makes the special elements seven meters wider than the standard elements.

## Dredging and land reclamation

The Dutch consortium FBC (a joint venture of Boskalis and Van Oord) won the dredging and land reclamation contract and was the first contractor to begin work on



Figure 2: Working harbour on Lolland, at the bottom of the picture the three halls of the tunnel element production facility including the basins (Photo: Femern A/S)

the project. The work includes dredging of the tunnel trench and constructing the working harbours on Lolland and Fehmarn. On Lolland, the working harbour was commissioned in 2022 (Figure 2).

The raw materials required for the tunnel element factory such as sand, gravel, and steel, will be brought in via this working harbour and the tunnel elements will be shipped out. The smaller working harbour on Fehmarn was completed in 2023. By April 2024, the tunnel trench was completed. The biggest challenges in dredging were the hard clay (which was eventually loosened by pre-ploughing), the strict tolerance (+200/-400 mm) for the bottom level of the trench, and the large boulders in the seabed that date from the ice age which weighed up to 60 tonnes. These boulders were individually raised from the seabed and used to build an artificial cliff in Denmark. The land reclamation is expected to be completed in the summer of 2025.

### Tunnel factory

The Femern Link Contractors (FLC) consortium, including the Dutch contractor BAM, began construction in 2020 of the world's largest tunnel factory, covering an area of approximately one square kilometer. In this factory, tunnel elements are built under strictly controlled conditions. In the summer of 2023, the first tunnel element segment was casted (see Figure 3).

A standard tunnel element, 217 meters long, consists of nine segments of over 24 meters each. The casting of such a segment is done in one continuous process, without cold joints (full-section-casting), and takes about 36 hours. The joints between the nine tunnel segments are connected with water-stop profiles to ensure a water-tight connection.



Figure 3: In the summer of 2023, the first tunnel element segment was casted (Photo: Femern A/S)

Shear keys between the segments ensure that the joints can transfer all the forces. At this moment, a total of ten complete tunnel elements have been produced on the five production lines in the tunnel factory and Danish King Frederik X has inaugurated the first element. Furthermore, standard elements 11 to 15 are in production. When all five production lines are operating at full swing, a new tunnel element will be completed approximately every two weeks. The special elements with a length of 38 meters are built on a separate (sixth) production line. They are not cast continuously but in five separate stages. The first special element is completed (see Figure 4) and construction of the following three special elements is progressing steadily. Two concrete plants have been realized to supply the production halls with the 3.2 million m<sup>3</sup> of concrete required for the project. An on-site covered storage facility for aggregates ensures full control over the composition, properties, and quality of the concrete mix.



Figure 4: The first completed Special Element (Photo: Femern A/S)

### Through the basins to the sea

Three basins are located between the production lines and the sea, each consisting of a deep and shallow part (see *Figure 2*). One basin serves two production lines. The tunnel segments are built on skidding beams fitted with Teflon. After construction of one segment, they are advanced 24 meters towards the basin and the sea, to make space for casting the next segment. Once two full tunnel elements (nine segments times two) are completed on two adjacent production lines, they are pushed into the shallow basin. The basin is then closed off from the production line (where production of the next elements will begin) using a large rolling gate. On the seaside, the deep end of the basin is closed off by means of a caisson gate (floating gate). After this, the water level in the basin is gradually increased. Once the water level reaches 10 meters above the sea level, the two tunnel elements will float and they are towed to the deep part of the basin. Once positioned in the deep part, the water level in the basins can be lowered back to sea level. The caisson gate is then floated up and out of the basin opening, allowing the tunnel elements to be towed out one by one into the working harbour. The skidding beams, roller door, and caisson door were finished in 2023. At the time of writing, three tunnel elements have been floated up (see *Figure 5*), ready for final outfitting in preparation for immersion.

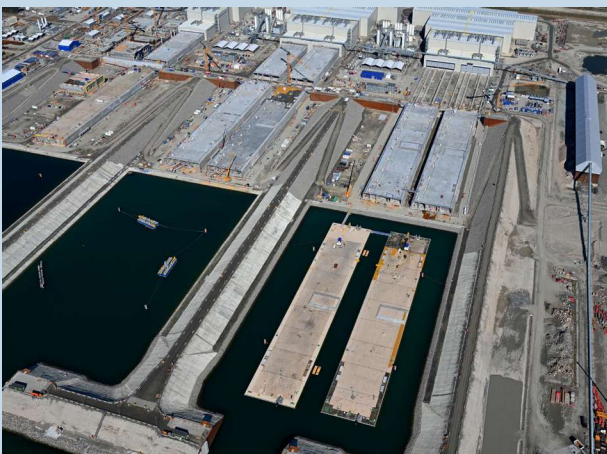


Figure 5: First elements floating in the basin (Photo: Femern A/S)

Transportation and immersion of the tunnel elements will require an extensive fleet that includes a multi-purpose pontoon for the installation of the gravel bed foundation, an immersion pontoon (see *Figure 6*) for transportation and immersion of the tunnel elements and a spreader pontoon for backfilling the tunnel trench after immersion of a tunnel element. The immersion pontoon is particularly larger and heavier than usual. The reason for this is that it was chosen to include a substantial amount of ballast concrete in the tunnel elements before they are immersed. This approach reduces the total transport by concrete mixer trucks through the immersed tunnel, which is an important factor during the construction phase for an 18-kilometer-long tunnel. The immersion pontoon arrived in Lolland in September 2024, where final commissioning is now in progress, followed by offshore trials. Once the sea trials are completed and the wave conditions in the Fehmarnbelt are favorable, immersion can begin in the summer of 2025.



Figure 6: Immersion pontoon IVY arrives in September 2024 in the working port of Lolland (Photo: Femern A/S)

### Tunnel portals

Parallel to the construction of the tunnel elements, the tunnel portals are being built on Lolland and Fehmarn, also by consortium FLC. The portals will be built in-situ in an open construction pit. An important milestone was reached in April 2024 with the removal of the temporary outer retaining dike around the tunnel portal on Lolland. The front end of the tunnel portal is now fully submerged (see *Figure 7*). Soon, the first tunnel element on the Danish side will be submerged and connected to the portal. At this moment, the Fehmarn portal on the German side is also ready for the first immersion operation. Elements will be immersed from both sides. A special closing element is planned to connect the two parts halfway along the Fehmarnbelt. The tunnel is scheduled to open in 2029. Until then, you will still have to choose either the ferry or the detour through Jutland when travelling to Scandinavia.



Figure 7: Outer retaining dike removal on Lolland, the tunnel portal is visible underwater (Photo: Femern A/S)

Tip: Should you be near the tunnel factory on Lolland (e.g. on holiday), the exhibition center in Rødby is a must-see for anyone curious about the Fehmarnbelt Tunnel. In addition, the recently opened 24 meters high viewpoint 'Pilen' offers a unique perspective on the tunnel's construction site.

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