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To cite this article: Kristian B Dahl et al 2017 IOP Conf. Ser.: Mater. Sci. Eng. 236 012056

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Tresfjord Bridge – a human friendly and traffic efficient structure

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Abstract. The E136 Tresfjord Bridge opened in October 2015, and crosses the Tresfjorden on the west coast of Norway. It is a concrete bridge with a total length of 1290 m, consisting of 19 viaduct spans, 60 m each, and a FCM (free cantilever method) main span of 160 m. The E136 is one of the most important transportation routes in the county of Møre and Romsdal and starts in Ålesund, and passes along Tresfjorden to Åndalsnes. The existing road is very narrow with speed limit of 60 km/h and characterizes by many accidents involving cars and people. The traffic flow is approximately ca 2500 vehicles a day, of this is 25% heavy vehicles. Those transport fresh salmon from the breeders in the fjords along the coast. To try to decrease the transportation time is very important for the fresh salmon. The bridge reduces the distance between Ålesund and Åndalsnes by 13 km. The speed limit is now 80 km/h, and with much less risk for accidents since there are separate lanes for cars and pedestrians over the whole bridge. This means that the bridge represents a human friendly and traffic efficient structure to the benefit for the people and the region.

1. Introduction
The Tresfjord Bridge which was opened in October 2015 and crossing Tresfjorden on the north-west coast of Norway, is a concrete bridge with a total length of 1290 m, consisting of 19 spans, 60 m each, and a FCM (free cantilever method) main span of 160 m, see Figure 1. The bridge has a box cross section with a maximum height of 9.2 m and a total width of 13.5 m, with 2 traffic lanes plus 1 pedestrian lane. The navigational channel is 60 m wide and 32 m high.

Figure 1. Tresfjord Bridge with total length 1290 m, built 2012-2015 at the west coast of Norway.
2. Foundations

2.1. Pile foundations
The foundations for the approach spans, a total of 13, are founded on pile groups of steel pipe piles ø1220, reinforced and concreted. Each group consists of 12-18 piles, typical 16 piles, see Figure 2. The maximum depth in the fjord is approximately 40 m. The piles are driven 5-6 m down in the very stiff moraine. The pile driving equipment was fixed to a steel jacket, supported by 4 steel legs standing on the seabed, thus making a very stable working platform for the pile driving. The piles were driven at an elevation 5:1. When the driving were completed the piles were fixed to a steel frame and cut at elevation +0.50. A bottom formwork was installed and a 400 mm thick concrete slab was concreted. This slab was the support for a precast concrete box which acted as a formwork for the pile cap. When installed the piles were reinforced with prefabricated reinforcement cages and concreted. There after the pile caps were reinforced and concreted.

![Figure 2](image1.jpg)

2.2. Caissons
The main span is founded on two caissons, one on bedrock, Axis 7, and one on soil seabed, consisting of dense, ground moraine, Axis 8.

2.2.1 Caissons in axis 7. The Caisson in Axis 7 is placed directly on rock at elevation -21. After underwater blasting the rock surface has been leveled by using AUV-concrete. Upon the concrete slab 3 circular foundations ø=2000 are established. The caisson is shaped like a cylinder with diameter 9.0 m and a wall thickness 0.45 m. The fender slab in top of the caisson has an outside diameter of 12 m and a height of 3.5 m. The total height is 21.5 m, see Figure 3. The caisson is constructed on a barge anchored at a quay not far from the site. After reaching a certain height, the barge was lowered until the caisson was floating. The caisson was completed up to the top when submerged in the water. The finished structure was then towed to the final position and lowered on the pre-prepared foundations by ballasting with water. The opening between the bottom of the caisson and the concrete slab was filled with concrete through pre-installed pipes. The caisson was then filled up with water saturated gravel before casting of the fender slab. 8 vertical steel pipes ø200 was embedded in the wall. Through these pipes holes were drilled 14 m down in rock in order to establish anchor for the rock anchors, 12ø0.6.
2.2.2 Caissons in axis 8. The deepest foundation, see Figure 4, in the FCM (free cantilever method) main span has a water depth of approximately 38 m. The thickness of the soil is approx. 20 m down to rock. Since the soil is very dense, it is impossible to excavate down to rock. Thus, the foundation is placed on the seabed after excavated approx. 2 m. In Norway, this is the first large caisson founded directly on soil seabed. The caisson resembles a GBS (gravity-based structure) similar to offshore structures. This, in conjunction with its size and general complexity, required a comprehensive design procedure.

The bottom slab consists of posttensioned lightweight aggregate concrete and has a diameter of approximately 24 m, whereas the shaft diameter ranges from 9 -15 m. The fender slab has a diameter of 12 m and a thickness of 3 m, constituting a monolithic base for the bridge pier. The caisson is filled with water saturated gravel. The weight of the structure is 3900 tonnes. It was designed with the in-house code MultiCon which is a postprocessor specifically developed for large concrete offshore structures. The construction took place on a barge at a quay a short distance from the bridge site, see Figure 5. When a specified part of the caisson was finished, the barge were lowered until the caisson was floating, and then the rest of the caisson was constructed. The caisson was 40 m from top to bottom. During the construction period it was stabilized with water, then afterwards it was towed to the site and placed into position with only 65 cm deviation from the correct position. On beforehand the seabed had been excavated in order to remove loose material and to be sure that the foundation surface was stiff. After excavating the top layer, a steel frame with 3 supports was installed and levelled, one of the supports were entrusted with guide in order to facilitate the positioning of caisson. The work on the bottom had to be performed by divers, the allowable working time at that depth was 30 min, and then it was back in the compression chamber for 12 h. Hence, it was a very time-consuming work. When in position on site the fender slab was reinforced and casted.
Figure 4. Caisson axis 8.

Figure 5. Caissons constructed at barge by quay.

3. Approach spans
The superstructure is a single box section with total width 13.5 m, web spacing 5.4 m, girder depths constant 3.0 m, span lengths 60 m. It was a span by span construction with a underslung gantry which used approx. 3 weeks on each span, see Figure 6. In each web it is 6 tendons 18ø0.62 and additional 6
tendons $31\times 0.62$ at each support. The superstructure is supported by rectangular shaped columns $1.6\times 5.2$ m and $2.4\times 5.2$ m respectively and height from 11 to 29 m.

![Figure 6. Approach spans with MSS.](image)

4. Main Bridge
The main bridge was constructed by the balanced cantilever method. The depths of section is varying from 3.0 m to 9.2 m for the main bridge. The thickness of the bottom slab varies from 0.35 m to 0.80 m, thickness of the webs from 0.35 m to 0.40 m. Form travelers were used to construct the free cantilevers, and typical section has a length of 5 m, produced on a weekly sequence, see Figure 7. In the deck slab it is maximum 52 tendons $19\times 0.62$, and in the bottom slab in center span it is 30 tendons $18\times 0.62$. Piers with box section $4.0 \times 5.4$ m and wall thickness 0.5 m support the superstructure. The piers are constructed with a climbing scaffolding system.

![Figure 7. Balanced cantilever method.](image)

5. Environmental effects
Route E136 is one of the most important transportation routes in the county of Møre and Romsdal. It starts in Aalesund, passes by Vestnes, go into the bottom of Tresfjorden, then out to Vikebukt and further on to Åndalsnes, through the valley of Romsdal before heading on to Oslo and Europe. The existing road along the fjord is characterized by a lot of spread housing alongside the road, many
accidents involving cars and people, speed limit of 60 and 70 km/h, and is a very narrow road with a
width in some places of 5.8 m. There are also several places along the existing road along the fjord
where there are avalanches, with downfall of stones. The traffic flow is approx. ca 2500 ADT, of this
is 25% heavy vehicles. The heavy vehicles transport mostly furniture from the factories around
Aalesund and fresh salmon from the breeders in the fjords along the coast. These items are transported
directly to the markets in Europe. It is very important to try to shorten the transportation in time,
especially for the fresh salmon. The bridge shortens the distance between Aalesund and Åndalsnes by
13 km, while the distance between Vikebukt and Vestsnes will be reduced by 22 km. The speed limit
will be 80 km/h, instead of 60 km/h -70 km/h, and with much less risk for accidents since there are
separate lanes for cars and pedestrians over the whole bridge. All this means that the bridge represents
a human friendly and traffic efficient structure to the benefit for the people and the region.

Figure 8: Completion of the key element in midspan.

6. Cost benefits
Total cost for the bridge inclusive roads is 800 mill NOK (100 mill EURO (2010)). Consequences (for
a period of 25 years):

- Reduced travel time 22 min
- Net value for society +490 mill NOK
- Reduced transportation cost for private sector 1230 mill NOK
- Reduced transportation cost for business sector 640 mill NOK
- Change in CO2-utslipp -4000 ton pr year
- Reduced accidents cost 80 mill NOK each year
- Reduced dead rate from car accidents 0.12 pr year

7. Conclusion
The completed Tresfjord Bridge, shown in Figure 9, reduces the distance between the two local towns
Ålesund and Åndalsnes by 13 km, and offers low risk for accidents since there are separate lanes for
cars and pedestrians. Moreover, the speed limit is increased. All in all, the bridge represents a human
friendly and traffic efficient structure to the benefit for the people and the region.
Figure 9. The completed Tresfjord Bridge.

References
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