Ferry free E39 –Fjord crossings Bjørnafjorden | 304624

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K12 - Architectural design

Norconsult
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Prodtex IFE Pure Logic HEYERDAHL ARKITEKTER AS H&BB MIKO MARINE AS BUKSÉR OG BERGING FORCE TECHNOLOGY SWERIM

REPORT

Project name:
CONCEPT DEVELOPMENT FLOATING BRIDGE E39 BJØRNAFJORDEN

Document name:
K12 - ARCHITECTURAL DESIGN

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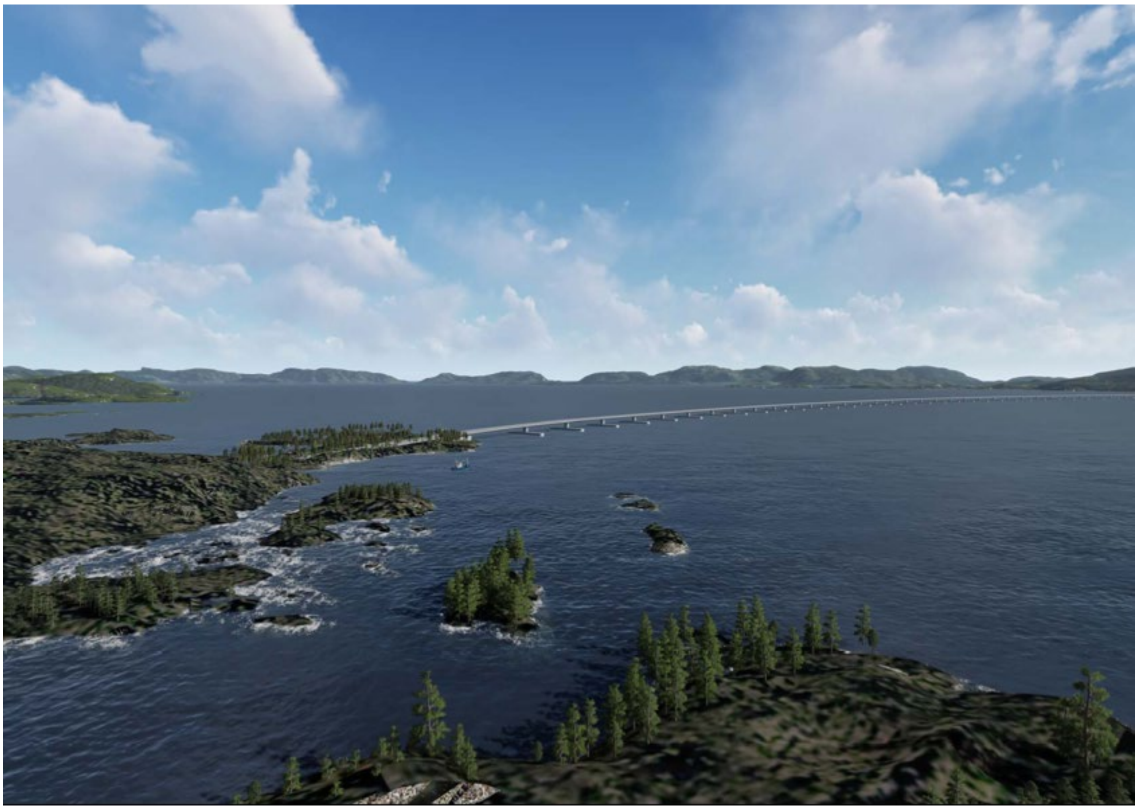
Summary

Generally

This report describes our work on the architectural design of the floating bridge. Heyerdahl Architects AS has been engaged in earlier phases of the project "E39 Stord - Os" with a proposal for an end anchored floating bridge. Experiences and assessments from previous work on the floating bridge have been continued during the latest phase of the project. This applies in particular to the assessment of the bridge seen against the landscape, the design of the cable-stayed bridge and the landing in the north towards Røtinga and Os.



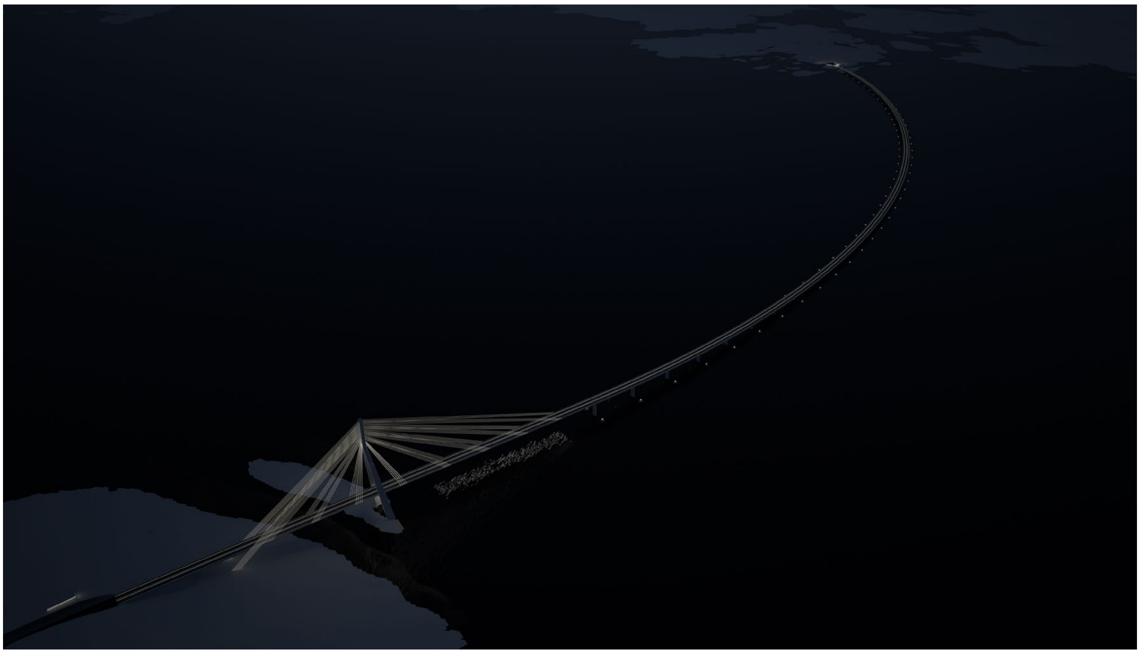
The north landfall. View from archipelago at Kobbavågen.

The work of the architects, besides seeking the best answer to the architectural challenges, has been to illustrate the consequences of the different construction principles. It was important to visualize, also for the whole team, the aesthetic and visual consequences of the different proposals.
Based on this work, 3 different proposals have been crystallized for the design of column and pontoon. In the final design proposal, we are using the same type of column and pontoon where it is not proposed submerged. For the cable-stayed bridge and bridge girder, only one design has been proposed. The same goes for the landfalls of the bridge.

Bridge and landscape

The crossing is 5 km. This is a long distance and by a curved bridge one gets a varied view along the curve and thus given varying perspectives of the bridge and the landscape. You will also, from the road, be able to experience the cable-stayed bridge seen from the side.

This will increase the visual experience of the floating bridge. By a straight line this would not be possible. This is, together with the “natural” shape, the main reason why the architects have recommended the concept for K12 to be continued.



E39, the crossing of Bjørnafjord. Seen towards the north and the archipelago at Kobbavågen. Night vision

The architects have proposed an asymmetrically constructed cable-stayed bridge. The cables will then point towards the sailing route. The bridge's position in the landscape will be better explained. In addition, the architects suggest that the pylon is tilted backwards. This will increase the asymmetric effect. The construction in this way visually spans the floating arch and lifts the bridge on land.
The vertical curvature has been adjusted in this phase of the project. The curve has been smoothed to achieve a better visual effect and to improve the driving experience.

The landfalls

The landfall of the bridge in the north, at Gulholmane has been shown previously with a large filling between the islet and Røtinga. At the same time, the neighboring area at Kobbavågen is an important recreation area.
The architects have therefore, on an earlier stage of the project, recommended the filling reduced in order to form a canal between Gulholmen and Røtinga. This for the sailing of smaller boats. In this way you will still be able to sail protected behind Gulholmen to Kobbavågen. The design of the landfall has been continued in this phase.

In the south, it is set as a premise from SVV that the landfall should be high in the terrain to avoid tunnels. For K12 this means that there will be a cut in the Skarvhella hill, which is visually exposed to Langenuen and Bjørnafjorden.
By the concept of K12 the cutting or intersection in the hill is not to be avoided. On the other hand, given the current situation, the road gives access to an amazing viewpoint at the top of Skarvhella. One can be proactive by adding a visitor center to this area. In this way, the center will become visible from both road and fjord and be a part of the landmark.


The bridge seen from the visitor center

The architectural design of the floating bridge

It has been quite a task for the architects, as well for the team, to learn how to design for the forces that affect the bridge girder, columns and the pontoons. This has, during the process, resulted in three different proposal for pontoon, columns and transition to the bridge girder. All the proposals have been architecturally designed to the same level of presentation. The bridge girder is visually equal on all proposals.

The first alternative has a submerged pontoon, completely covered by the sea. Up of the sea, rise a center column and the the sides two large “floats”. They are all firm conected to the submerged pontoon. The option is currently set aside due to a possebility of "climbing" on to the pontoon at ships impact.

The second alternative is a traditional pontoon - column construction. The pontoon floats on the sea and are carrying the column. This option has, by the engineers, been given the most attention and is quality assured for use.

The third alternative has similar pontoons as the second alternative, but the top of the columns is changed, where it is placed a rig of closed steel profiles. The principle is considered very interesting aesthetic and possible to produce effectively with modern production methods. The concept is briefly calculated and assumed clarified. It is recommended that the concept be fully calculated in the next phase of the project.

Columns and pontoons

The columns in the second alternative is slightly cone-shaped against the top and a fracture bracket. At the top of the column there is an opposite cone-like shape that transmits the forces to the bridge girder. The steel rig in the second and third gives the possibility to increase the span and thus reduce the costs.

The pontoon is given a shape that meets the sea in a soft way. The pontoon is arching it´s back to visually carry the column. The pontoons are mostly welded up by single-curved steel plates. Only a small part has double curved surfaces

The bridge seen towards the south, floating pontoon and cone-shaped column

The bridge seen towards the south, floating pontoon and steel rig column

The bridge seen towards the south, submerged pontoon and steel rig column

Table of Content

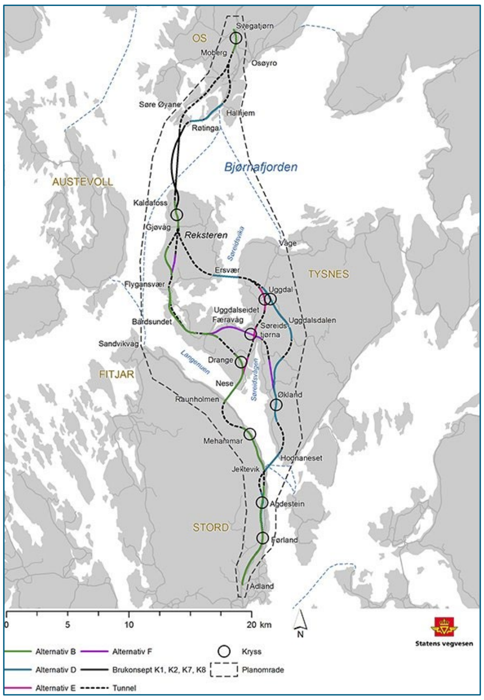
1 INTRODUCTION

1.1 Current report

This report describes our work on the architectural design of the floating bridge.
Heyerdahl Architects AS has been engaged in earlier phases of the project "E39 Stord - Os" with a proposal for an end anchored floating bridge. Experiences and assessments from previous work on the floating bridge have been continued during the latest phase of the project. This applies in particular to the assessment of the bridge in the landscape, the design of the cable-stayed bridge and the landfall in the north towards Røtinga and Os.
Our report for this phase describes our contribution in choosing a concept. Furthermore, it describes our work with detailed design of the cable-stayed bridge, the landfalls of the bridge together with proposals for the design of pontoon and columns.
We have also served the team with illustrations and animations of driving experiences along the different bridge concepts as well as illustrations of the different principles of construction.

1.2 Project context

Statens vegvesen (SVV) has been commissioned by the Norwegian Ministry of Transport and Communications to develop plans for a ferry free coastal highway E39 between Kristiansand and Trondheim. The 1100 km long coastal corridor comprise today 8 ferry connections, most of them wide and deep fjord crossings that will require massive investments and longer spanning structures than previously installed in Norway. Based on the choice of concept evaluation (KVU) E39 Aksdal Bergen, the Ministry of Transport and Communications has decided that E39 shall cross Bjørnafjorden between Reksteren and Os.
SVV is finalizing the work on a governmental regional plan with consequence assessment for E39 Stord-Os. This plan recommends a route from Stord to Os, including crossing solution for Bjørnafjorden, and shall be approved by the ministry of Local Government and Modernisation. In this fifth phase of the concept development, only floating bridge alternatives remain under consideration.



1.3 Project team

Norconsult AS and Dr.techn.Olav Olsen AS have a joint work collaboration for execution of this project. Norconsult is the largest multidiscipline consultant in Norway, and is a leading player within engineering for transportation and communication. Dr.techn.Olav Olsen is an independent structural engineering and marine technology consultant firm, who has a specialty in design of large floating structures. The team has been strengthened with selected subcontractors who are all highly qualified within their respective areas of expertise:

- Prodtex AS is a consultancy company specializing in the development of modern production and design processes. Prodtex sits on a highly qualified staff who have experience from design and operation of automated factories, where robots are used to handle materials and to carry out welding processes.

- Pure Logic AS is a consultancy firm specializing in cost- and uncertainty analyses for prediction of design effects to optimize large-scale constructs, ensuring optimal feedback for a multidisciplinary project team.
- Institute for Energy Technology (IFE) is an independent nonprofit foundation with 600 employees dedicated to research on energy technologies. IFE has been working on high-performance computing software based on the Finite-Element-Method for the industry, wind, wind loads and aero-elasticity for more than 40 years.
- Buksér og Berging AS (BB) provides turn-key solutions, quality vessels and maritime personnel for the marine operations market. BB is currently operating 30 vessels for harbour assistance, project work and offshore support from headquarter at Lysaker, Norway.
- Miko Marine AS is a Norwegian registered company, established in 1996. The company specializes in products and services for oil pollution prevention and in-water repair of ship and floating rigs, and is further offering marine operation services for transport, handling and installation of heavy construction elements in the marine environment.
- Heyerdahl Arkitekter AS has in the last 20 years been providing architect services to major national infrastructural projects, both for roads and rails. The company shares has been sold to Norconsult, and the companies will be merged by 2020.
- Haug og Blom-Bakke AS is a structural engineering consultancy firm, who has extensive experience in bridge design.
- FORCE Technology AS is engineering company supplying assistance within many fields, and has in this project phase provided services within corrosion protection by use of coating technology and inspection/maintenance/monitoring.
- Swerim is a newly founded Metals and Mining research institute. It originates from Swerea-KIMAB and Swerea-MEFOS and the metals research institute IM founded in 1921. Core competences are within Manufacturing of and with metals, including application technologies for infrastructure, vehicles / transport, and the manufacturing industry.

In order to strengthen our expertise further on risk and uncertainties management in execution of large construction projects Kåre Dybwad has been seconded to the team as a consultant.

1.4 Project scope

The objective of the current project phase is to develop 4 nominated floating bridge concepts, document all 4 concepts sufficiently for ranking, and recommend the best suited alternative. The characteristics of the 4 concepts are as follows:

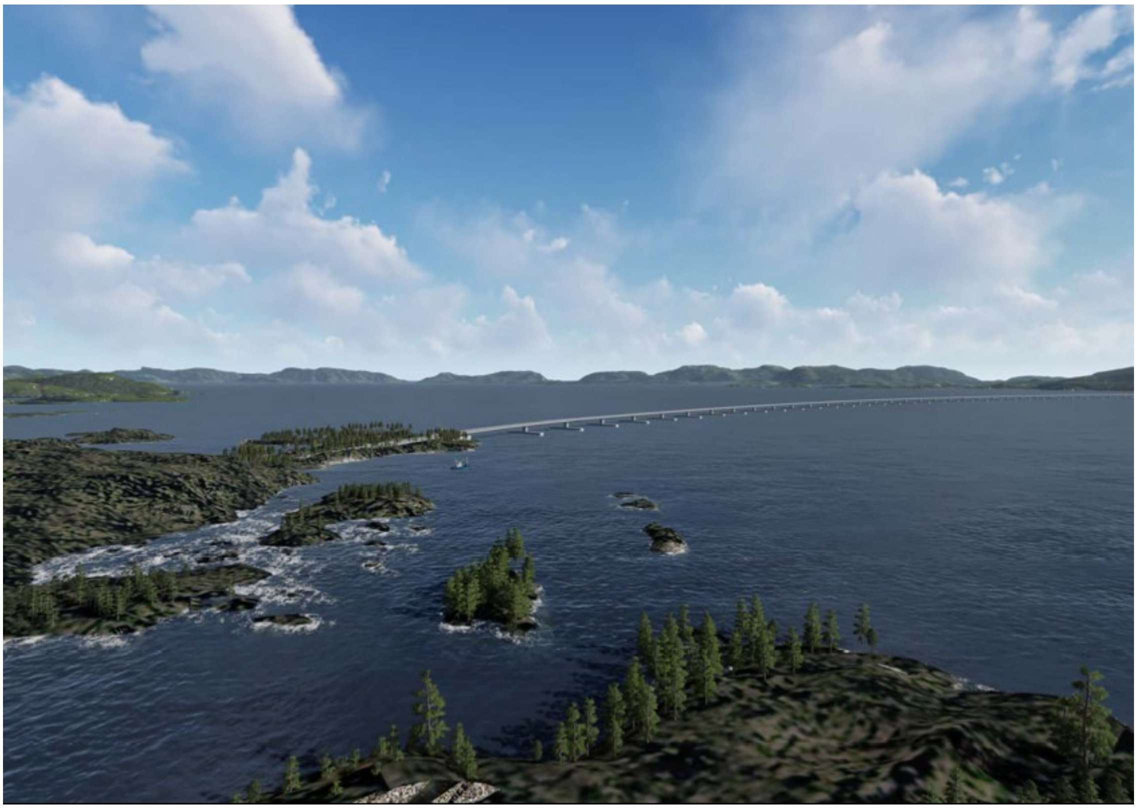
- K11: End-anchored floating bridge. In previous phase named K7.
- K12: End-anchored floating bridge with mooring system for increase robustness and redundancy.
- K13: Straight side-anchored bridge with expansion joint. In previous phase named K8.
- K14: Side-anchored bridge without expansion joint.

In order to make the correct recommendation all available documentation from previous phases have been thoroughly examined. Design and construction premises as well as selection criteria have been carefully considered and discussed with the Client. This form basis for the documentation of work performed and the conclusions presented. Key tasks are:

- Global analyses including sensitivity studies and validation of results
- Prediction of aerodynamic loads
- Prediction of hydrodynamic loads
- Ship impact analyses, investigation of local and global effects
- Fatigue analyses
- Design of structural elements
- Marine geotechnical evaluations
- Steel fabrication
- Bridge assembly and installation
- Architectural design
- Risk assessment

2 GENERAL CONSIDERATIONS

This report describes our work on the architectural design of the floating bridge. Heyerdahl Architects AS has been engaged in earlier phases of the project "E39 Stord - Os" with a proposal for an end anchored floating bridge. Experiences and assessments from previous work on the floating bridge have been continued during the latest phase of the project. This applies in particular to the assessment of the bridge seen against the landscape, the design of the cable-stayed bridge and the landfall in the north towards Røtinga and Os.



> *Figure 2-1: The north landfall, seen from the archipelago and the recreation area at Kobbavågen*

The architects have also contributed to the assessment of the four different bridge concepts. The contribution is shown in the consolidated technical reports. The consolidated technical report for K12 states that K12 is the best proposal architecturally, but that the landing in the south is somewhat problematic in the overall landscape picture.
Landfall in the south has therefore been given great attention.
The landfall in the north was locked satisfactorily at an earlier stage of the project, and the proposal has been transferred to this phase.

The discussion around the cable-stayed bridge has been important. The theme has been questions about symmetrical or asymmetrical bridge, and whether the tower can be tilted. We are pleased to note that the asymmetric solution with tilted towers is accepted and verified. In this phase, the details of the tower and the cabling have been clarified. The assessments from the previous phase have otherwise been continued.

The work of the architects, besides seeking the best answers to the architectural challenges, have been to illustrate the consequences of the different construction principles. It was important to visualize, also for the whole team, the aesthetic and visual consequences of the different proposals.

Pontoon and column have been given great attention. There will be about 40 columns along the bridge, and costs at each point will be very important. In addition, columns and pontoons can create a visual wall over the fjord as seen along the bridge path. It is therefore important to minimize the size of the shapes by optimization of technical solutions, architectural form, production technique and economy.
Up to now, 3 different proposals have been crystallized for the design of columns and pontoons. In the final design proposal, we have somewhat minimized the differences by using the same column type and the same type of pontoon where it is not proposed submerged.

For the cable-stayed bridge and bridge girder, only one design has been proposed. The same goes for the landfall of the bridge, both in the north and the south.

3 BRIDGE AND LANDSCAPE

Bjørnafjorden is a beautiful and open fjord landscape with many islands, islets and reefs. The fjord is an important outdoor area for both locals and visitors from Bergen. Especially in the afternoon sun is Kobbavågen on Røtinga a favorite place for small boats.
Placing a bridge over Bjørnafjorden in this neighborhood is demanding and the discussion about the project has also been polarized and become a political issue.

It is a political decision whether the bridge is to be built or not. Our mission, as architects, is to find a solution that are as environmentally friendly as possible. At the same time we must dare to give the bridge an architectural strength and clarity that can make the bridge a landmark and even a pride for the region. The illustrations of the project so far indicated this may be achievable.

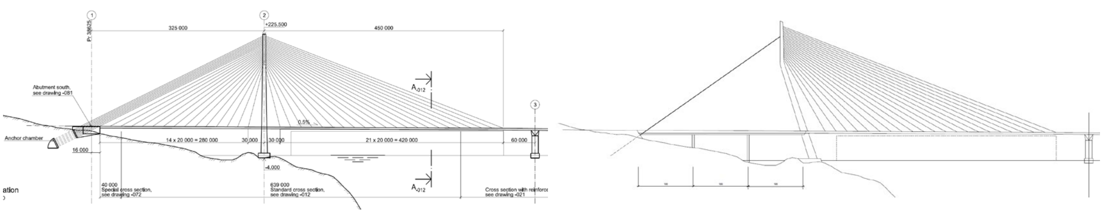
The bridge is located in the mouth of Bjørnafjorden where the fjord meets the strait of Langenuen. The bridge is parallel to the strait and in this way it marks the transition to the strait and further out the North Sea.

Traditionally, a bridge is built in the shortest possible straight line between points A and B. However, the crossing of Bjørnafjorden must be carried out with a floating bridge construction. It will, if attached at each end, behave like a rope and float in the sea in an arc shape. Given an end anchoring, the arch will be the "natural" shape.
Should one construct a straight bridge, one must, with great effort, force the construction into position at each column point.
K12 is a merged solution with end anchoring and 2 fix point along the arch. This does not influence the overall view, but makes the landfall and the connection at the tower less strained architecturally

The crossing is 5 km. This is a long distance and by a curved bridge one gets a varied view along the curve and thus given varying perspectives of the bridge and the landscape. You will also, from the road, be able to experience the cable-stayed bridge seen from the side. This enhances the experience of the floating bridge. By a straight line this would not be possible. This is, together with the “natural shape”, the main reason why the architects have recommended the concept K12 to be continued.

> *Figure 3-1: The crossing of Bjørnafjorden with the tower and visiting center in the south, and the recreation archipelago in the north. The walking and cycling path is situated on the west side of the bridge and connects both to the visitor center and the archipelago*

In an earlier phase of the project, the engineers have shown a symmetrical cable-stayed bridge. From an architectural point of view, this was seen as less fortunate. The tower for cable-stayed bridge stands near by land. Half of the bridge then spans land, while the rest of the bridge spans the sea. Seen from a ship, a symmetry about the pylon should indicate equal sailing on both sides, which is not the case.
The architects have proposed an asymmetrically constructed cable-stayed bridge. The cables will then point towards the sailing route and the bridge's position in the landscape is better explained. In addition, the architects suggest that the tower is tilted towards land. This will increase the asymmetric effect, and at the same time the tilted tower visually spans the floating arch and lifts the bridge on to the landfall.



> *Figure 3-2: Symmetric cable-stayed bridge (left) and asymmetric cable-stayed bridge with tilted tower (right)*

The vertical curvature of the bridge has been a theme during the process. From an engineering point of view, it was desirable to get down as quickly as possible to the general bridge height. This created a vertical curvature that seemed architecturally unfortunate, and it was desirable to straighten out the curve to some extent.

An animation of the driving experience along the bridge showed that the straightening was absolutely necessary. The curvature has been adjusted satisfactorily. one can still see the rise up towards the cable-stayed bridge, but the transition curves have now become acceptable better.

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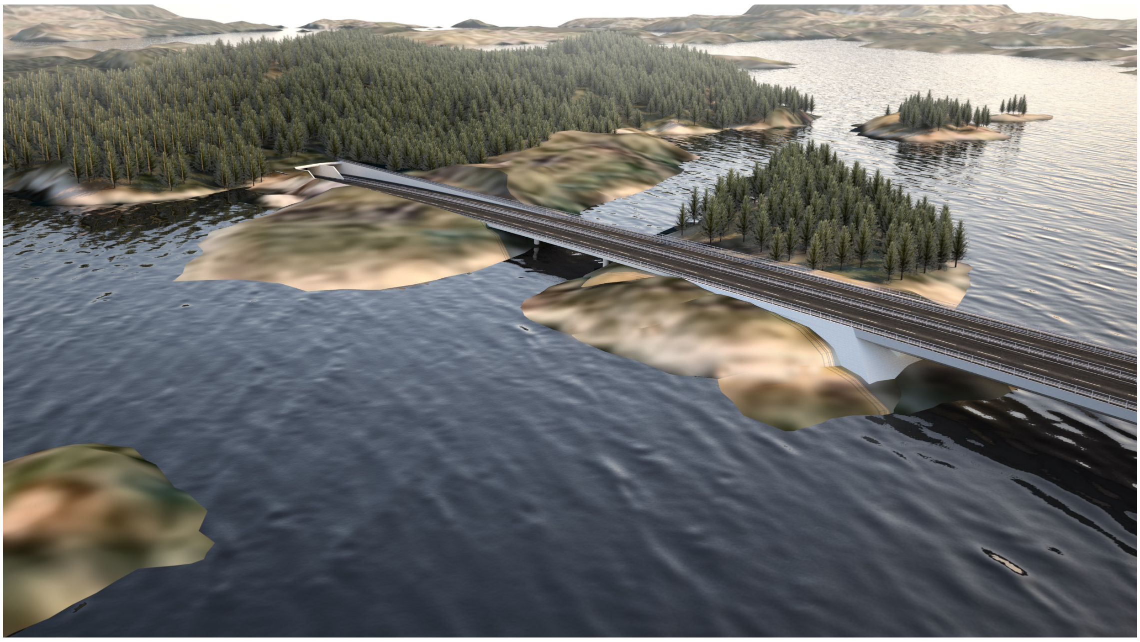
> *Figure 3-3: Asymmetric cable-stayed bridge with tilted tower, seen towards the west*

4 THE LANDFALLS

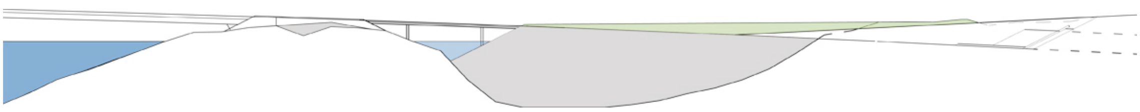
The landfall of the bridge in the north, at Gulholmane has been shown with a large filling between the islet and Røtinga. It is desirable to fill larger amounts of blasting stones from the tunnel drive into the sea in this area. At the same time, the neighboring area at Kobbavågen is an important recreation area.
The architects have therefore previously recommended the filling be reduced in order to form a canal between Gulholmen and Røtinga. This for the sailing of smaller boats. In this way you will still be able to sail protected behind Gulholmen to Kobbavågen. The landfall at Gulholmen is shown with a low concrete foundation that locks the bridge girder to the landing. The solution also requires a short road bridge over the canal before entering the area by the tunnel portal. At the end of the canal bridge the sidewalk and cycle path turn off from the E39 and are laid on terrain over Røtinga



> *Figure 4-1: The north landfall of the bridge*

> *Figure 4-2: The north landfall, seen from sea level*

> *Figure 4-3: The north landfall. The canal*

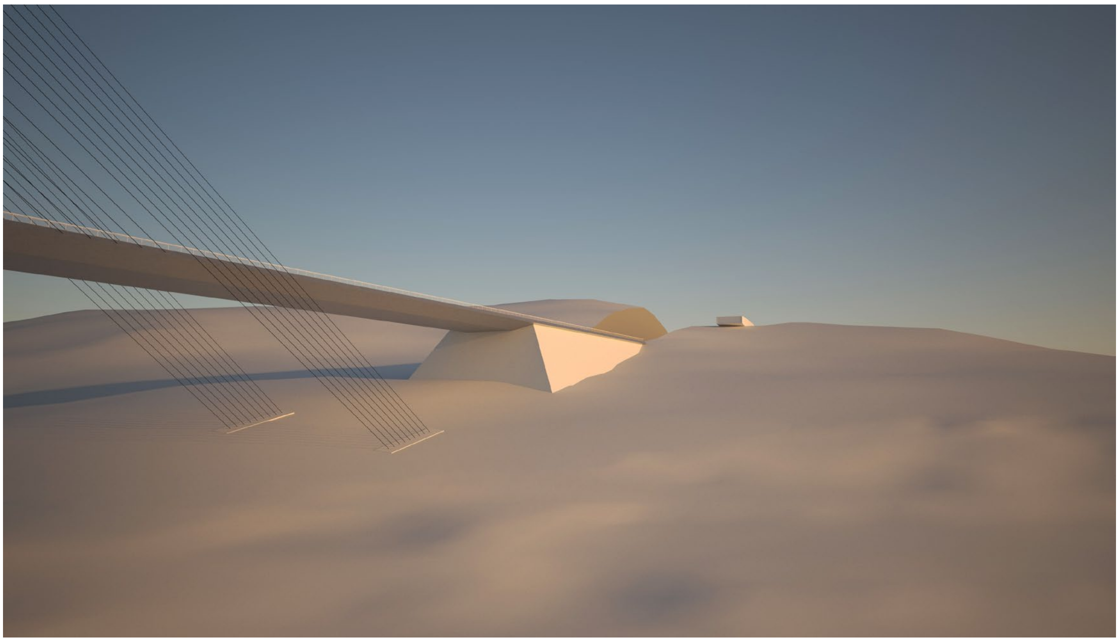


> *Figure 4-4: Cross-section*

In the south, it is set as a premise from SVV that the landfall should lie high in the terrain to avoid tunnels. For K12 this means that there will be a cut in the Skarvhella hill, lying visually exposed to Langenuen and Bjørnafjorden. "Skarv" means a bend or rounding, and it forms a significant landmark between the fjord and the strait.

The landfall in the south, however, is a significantly greater intervention in the landscape than the intersection in the hill. The bridge, as it is now planned, will have a landfall with a height of approx. 15 meters. This is a considerable height compared to nearby low-rise residential buildings. In addition, the construction is exposed on the headland towards the strait and the fjord. Architecturally, this is not acceptable. The bridge must therefore be extended so that the landfall can be retracted. It will then be less exposed and, in addition, will be significantly reduced in height. The illustrations show the projected and unacceptable solution.

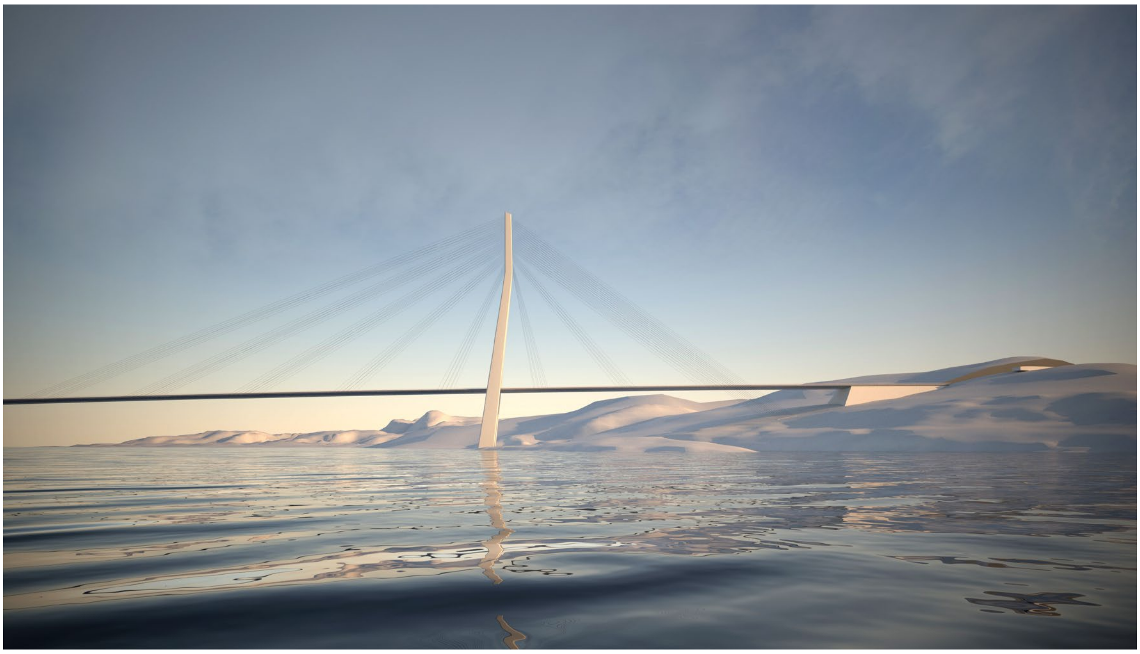
By the concept of K12 the cutting or intersection in the hill is not to be avoided. The cutting may appear as a wound in the landscape unless you make larger landscaping adjustments. This will have to be processed in later phases of the project. One can find a better position for a cutting, for example on the east side of Skarvehella. The concept K14 has such a landing. To achieve this for K12, the towers must be moved slightly to the east. This is beyond the scope of the project, and is not dealt with here.



> *Figure 4-5: The south landfall and visitor center*

On the other hand, in the current situation, the road gives access to an amazing viewpoint at the top of Skarvhella. Here you can get an overview of the entire fjord landscape together with a bird's eye view of the bridge. One can be proactive by adding a visitor center to this area. In this way, the center will become visible from both road and fjord and thus be a part of the landmark.
The access to the visitor center has not been treated in this phase, but it will be possible to use the local roads in the area and to connect to the nearest intersection in the south.

> *Figure 4-6: The bridge seen from a visitor center*



> *Figure 4-7: Landfall south seen from the strait*

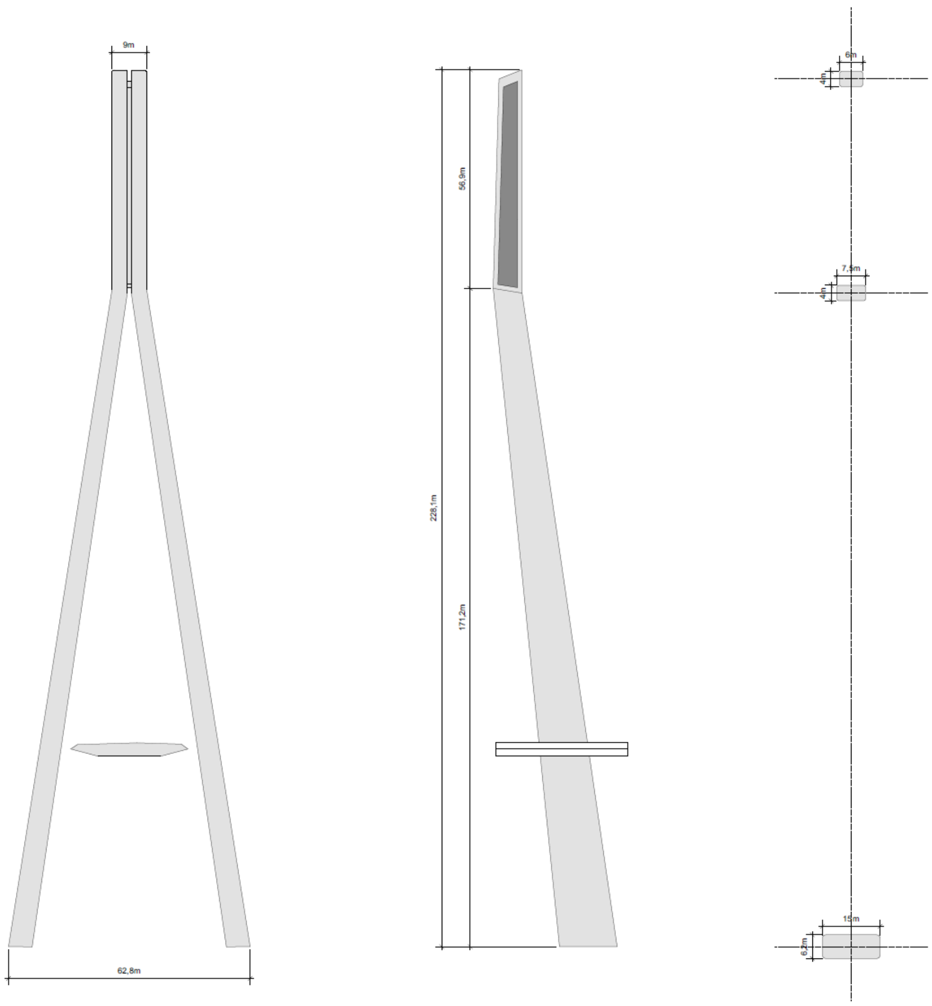
5 THE TOWER

The tower is tilted backwards to provide the necessary asymmetry at the given bridge location. In addition, tilting will visually drag the floating bridge, keep it in position and lift it up on land.

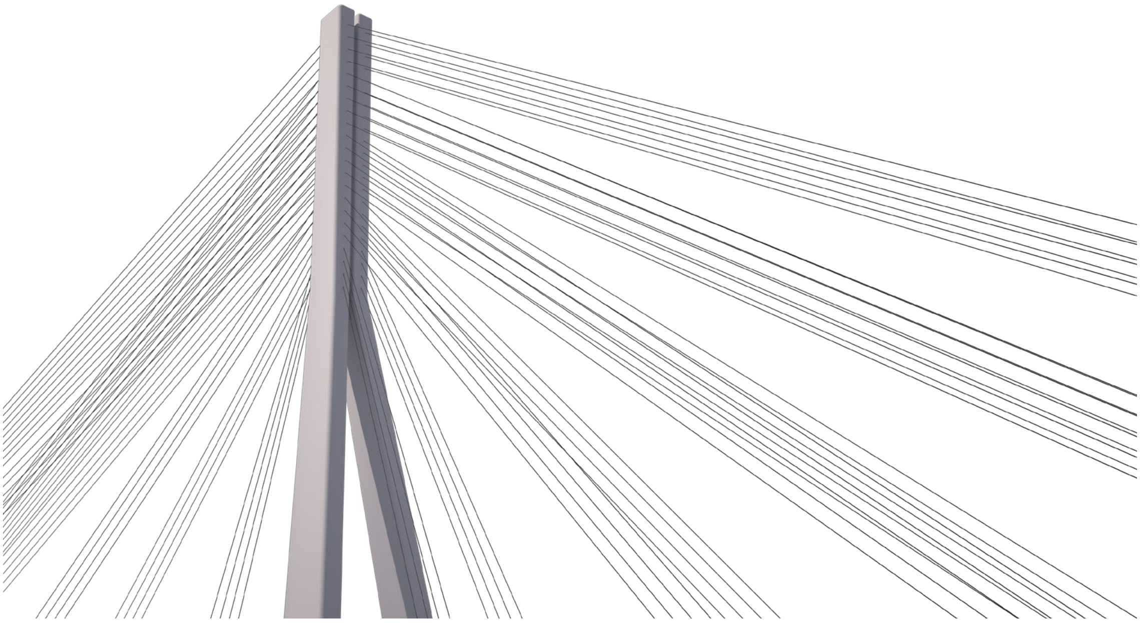
At the top of the tower, in the area where the cables are attached, the tower is straight up in the vertical position. The tower has got a so-called swan neck shape. The shape provides a clearly defined area for cable fixing and gives the tower a defined architectural finish.
The tower's legs are led as independent forms, from the bottom to the top. The legs dimensions are decreasing gradually toward the top. At the top, the legs are architecturally separated and defined by a recessed “adapter”. The construction is entirely cast in concrete.

The tower does not have the traditional crossbeam since the bridge girder does not connect to the tower. This is due to movements from the floating bridge which are first received at the landfall construction.

The cables are assembled in bundles and mounted to the bridge at a distance of about 90 meters. A stronger bundle is led from the tower backwards and to concrete foundation at the ground level.



> *Figure 5-1: Front and cross-section of the tower*



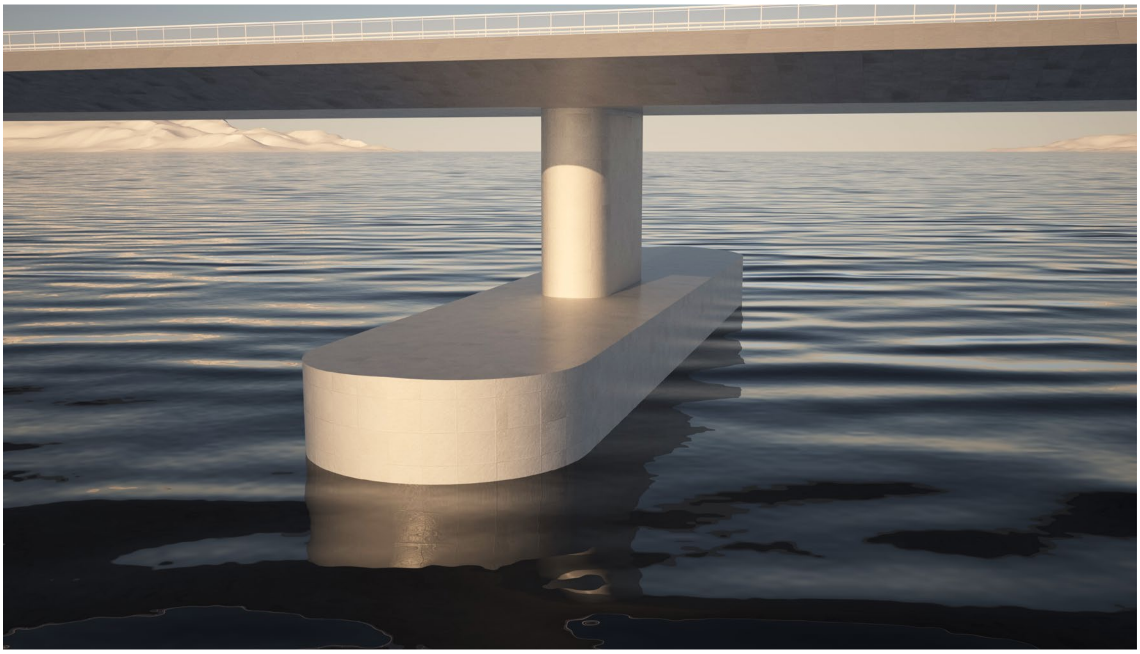
> *Figure 5-2: Top of the tower, detail*

6 THE FLOATING BRIDGE

The floating part of the bridge consists of the bridge box, columns and pontoons. All elements are dimensioned and calculated based on air and hydrodynamic behavior and the transfer of forces between the pontoon, column and bridge beam. The simple pontoon and column design, called the 0 - alternative, and has not been considered architecturally. The engineer design has been a starting point for the architectural concept development. Both the pontoon and the column has later been given architectural articulations. The aerodynamic design of the bridge grider has been continued unchanged as part of the architectural concept.

6.1 0-alternative

The pontoon appears as a box with rounded ends, and with a length about 60 meters. Width varies from 12 to 17 meters depending on the height of the column. The pontoon has a height of 4 meters above the sea level. Architecturally, this pontoon gives a very heavy and massive impression. The pontoon has a shape similar to a regular concrete foundation, standing on the bottom of the fjord. The design of the pontoon does not clearly say that this is a floating bridge. The story the design tells is rather the opposite.



> *Figure 6-1: Pontoon, given in the 0-alternativ. The height of the pontoon is 4 meters above the sea level.*

The column is of steel and given a rectangular shape with rounded ends. The base area is about 4 x 8 meters. The dimensions increase with increasing column height. At the top of the pillar a weak zone has been added. This to prevent mechanical stress from destroying the bridge girder.
The joint is not architecturally articulated, but is resolved with thinner and more pliable steel plates in the transition to «VUT"

> Figure 6-2: The column given in the 0-alternativ has dimension of 4 x 8 meters.

> Figure 6-3: 0-alternativ. The pontoons do not look like they are floating. They are more similar to foundations standing on the bottom of the fjord. The dimensions of the pontoon and columns can, in certain angels, create a visual wall across the fjord.

The 0 alternative provides a bridge with the most closing impression. From a distance, all dimensions become small, especially from a frontal perspective. It then becomes difficult to distinguish between details and different designs of the elements.

If the bridge is experienced up close, the situation will be something completely different. From land or from a smaller boat, the bridge viewed at an angle along the bridge path will be perceived as a wall. In particular, the 4-meter-high and 60-meter-long pontoons will be perceived as a closing wall. From given perspectives, the sea will be visually shut off from the fjord. This is somewhat unfortunate in that the bridge is at the mouth of the Bjørnafjord.

The bridge is and will be a portal to Bjørnafjord, In view of the landscape it will be desirable to create an architecture that provides maximum visual openness for this portal. In this context, the most important thing to note is the light reflections from the sea and that one get as large and coherent reflective surface as possible past the bridge.

6.2 Architectural articulation

The columns

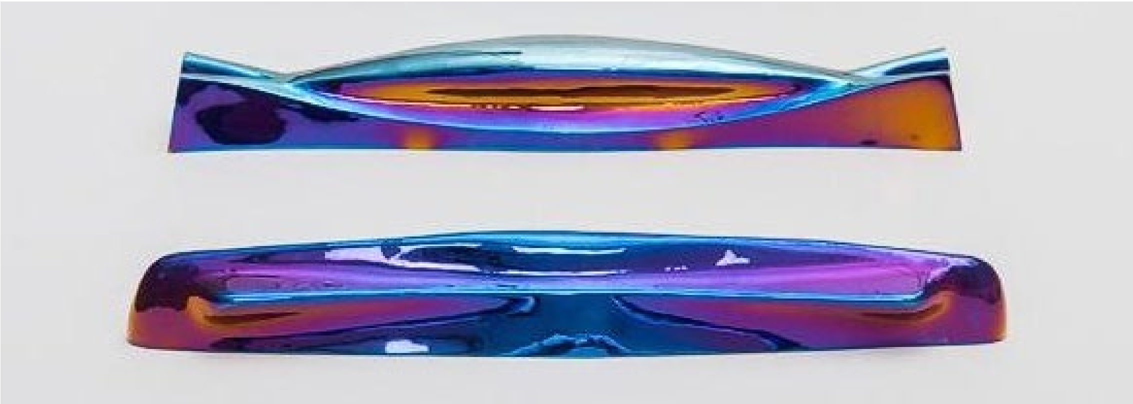
The 0 - alternative has shown columns that it is absolutely necessary to articulate architecturally. Not much room is given, but more elegance can be achieved by slightly giving the column a cone-to-peak shape. The "vuten" shown in the 0 alternative can advantageously be replaced by a reversed steel cone. The weak-zone is placed at the top of the column at the transition to the cone.

Cone-shaped column with «vut» on the top

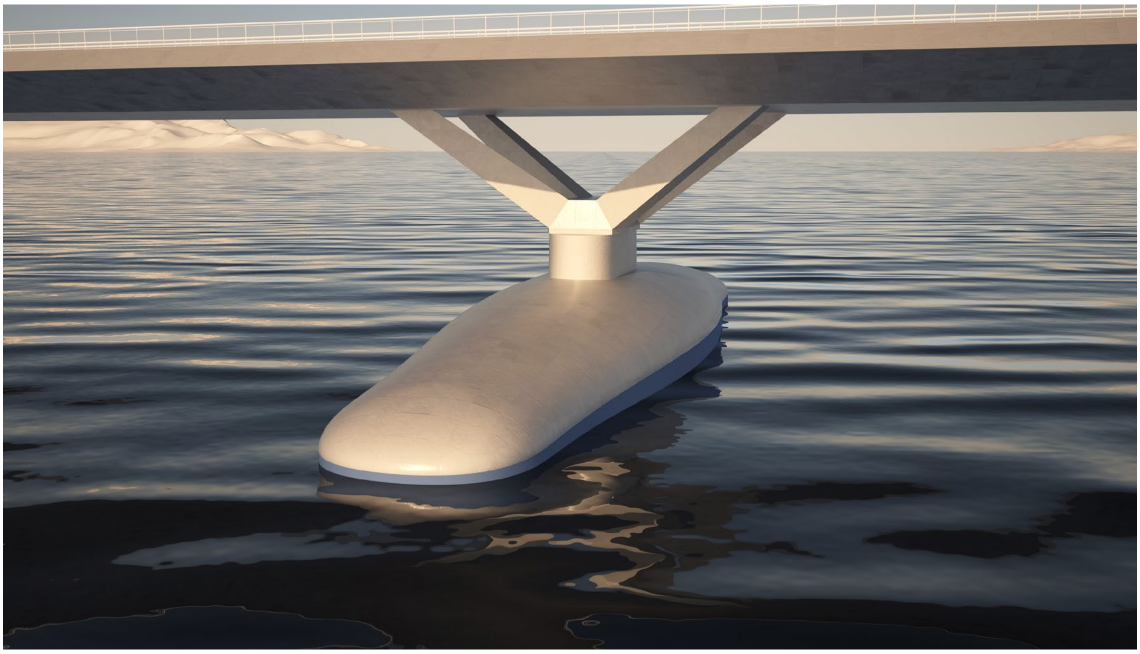
Cone-shaped column with steel rig on top

Architecturally, the solution with the tapered head is less interesting. It is and will only be a "vut". By putting a steel rig on top of the column, the construction becomes architecturally more interesting. The forces are better explained and the transition from pillar and bridge becomes more open and expressive.

The rig is built up of closed steel profiles. At the bottom of the rig the profiles have full standing heights. The steel rigs are considered very interesting because of the aesthetics, but it might as well have an economical advantage. The span for the bridge grider is set to 120 meters. If the size of the rig is set to the maximum width of the pontoon / "floaters", the distance between the columns can be increased by 12 meters, given the same span of the grids. That is a 10% increase and will mean 10% fewer pontoons and columns.



> *Figure 6-4: Bård Breiviks «boat shapes» are made in different techniques, - here in colored glass*

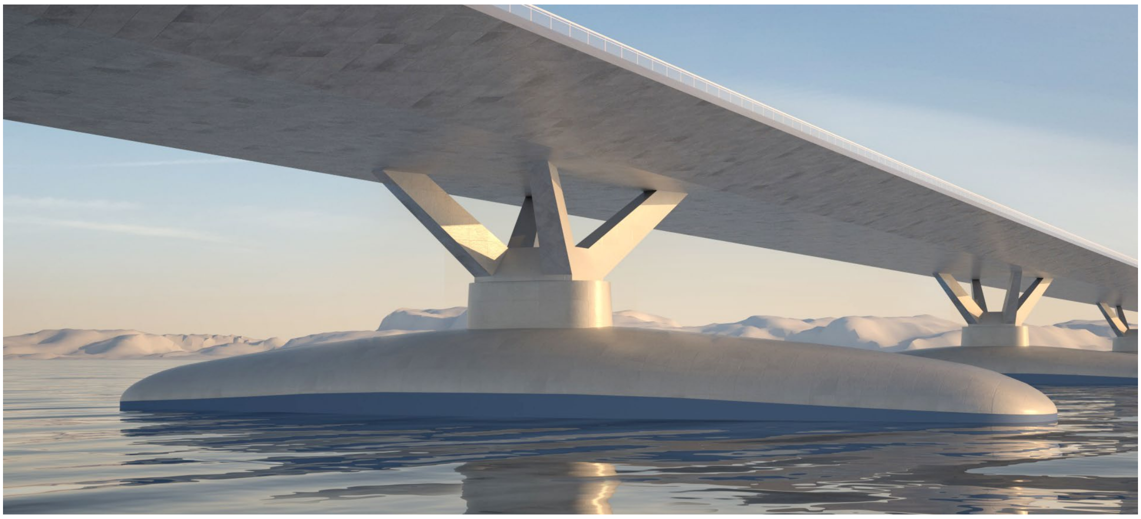


> *Figure 6-5: «Dolphin» pontoon with short column and steel rig*

The pontoon

There have been discussions about whether the pontoon should float on the surface or be submerged in the sea. Due to the potential for ship impact and climbing on the pontoon, a submerged solution has so far been abandoned.

Given the solution with a pontoon floating on the sea, it has been important to give it a shape that shows that it floats. This is done by giving the pontoon a rounded and soft shape - like a dolphin. Our design proposal is inspired by the sculptor Bård Breivik's "boat shapes"



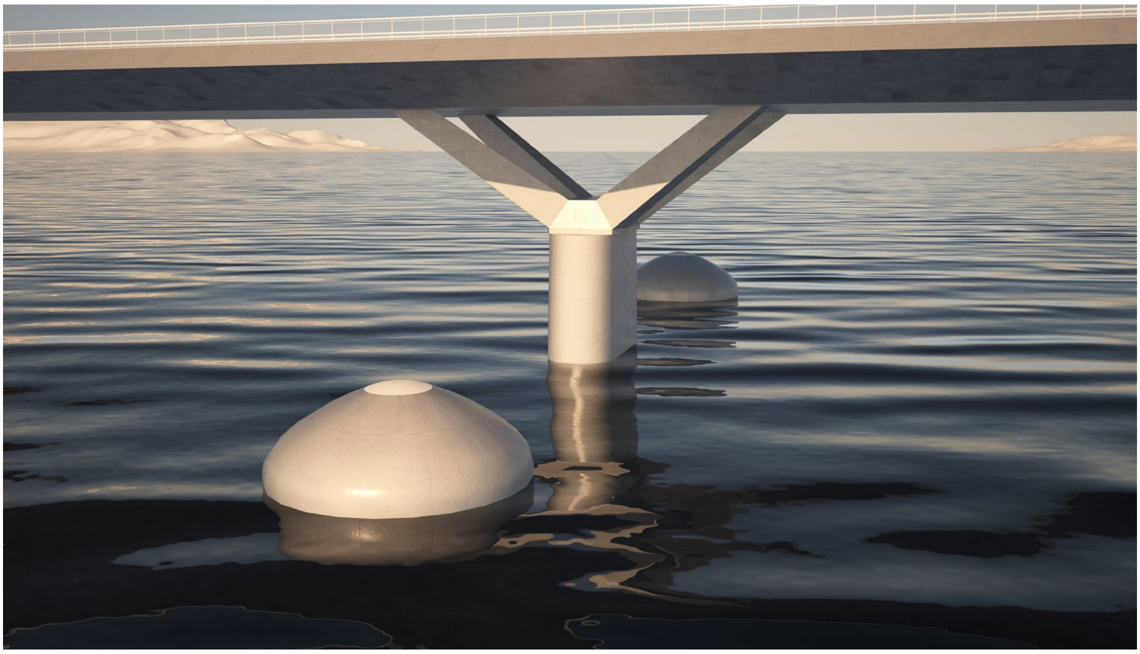
> *Figure 6-6: «The dolphin pontoon» with arching back bearing the column*

The pontoon is arching its back to visually carry the column, and transfer the forces down to the floating body. In order to clarify that the pontoon floats at the right height, it has been given and marks waterline, slightly curved. The curved line, along with the arching back, is importer to provide visual strength to the pontoon.
The shape of the pontoon meets the sea softly, like a rock cut down by the waves. The sea will wash over the pontoon in a smooth manner. This is in contrast to a 4 meter high vertical surface. Only the sound of these two different situations will be compelling for the choice.

The tripod pontoon
It is highly possible that the submerged pontoon may become relevant again. First, the requirements regarding forces from ship impact have been reduced. Secondly, the pontoon has a rounded shape that will slip off on impact.Thirdly, the column is constructed with a weak zone at the transition to the grider. This means that the pontoon and pillar, at a given force, will bend off without the grider and the bridge being destroyed.

The pontoon is lowered to less than 1 meter below the surface of the sea, and is shaped like a tripod. In the middle stands the column and on each side there are two stabilizing "floaters". They are fixed parts of the pontoon. Together, they form «Neptune's tripod». When waves and swells hit the submerged pontoon and the sea will break over the pontoons. The bearing of the bridge will be revealed and visible. By calm and mirroring sea it all becomes magical. The bridge strolls across the fjord with the help from Neptune's fork.

The effect in the landscape is considerable. The sea gets a continuous reflective surface past the bridge, and the visual connection that the sea provides between Bjørnafjoden and the strait at the Langenuen is maintained. There is thus a significant difference in the experience of the bridge between floating and submerged pontoons.



> *Figure 6-7: Submerged pontoon with column and steel rig*

Conclusion
Architecturally we would recommend a slightly tapered column with a steel rig that transmits the forces from bridge to column. It is further recommended that one chooses the submerged pontoon. If it turns out that a submerged pontoon will be impossible, then we would recommend the floating "dolphin" pontoon.

> *Figure 6-8: Submerged pontoon seen from the sea*

> Figure 6-9: Floating bridge with pontoon, column and rig. Seen towards the south. The pontoon close for the view

> Figure 6-10: Floating bridge with submerged pontoon, column and rig. Seen towards the south. The submerged pontoon open up for the view along the fjord

> *Figure 6-11: «Floating dolphin pontoon» The bridge seen towards the north. From this angel the pontoon creates a wall, dividing the fjord.*

> *Figure 6-12: Submerged pontoon. The bridge seen towards the north. The fjord is passing through*

7 LIGHTING

Traditional road lighting will undoubtedly provide significant light pollution to the surroundings. The bridge will be exposed in the Bjørnafjord, - visible to everyone. Roadlight from masts will illuminate the entire bridge, the fixtures will be exposed, and you will get unwanted light over the water surface near the bridge. On the whole, the bridge will become visually dominant throughout the night and part of the day due to the lighting.
The regulations are strict in this area, and with the speed limit of 110 km / h, the possibilities for alternatives will not be particularly large.

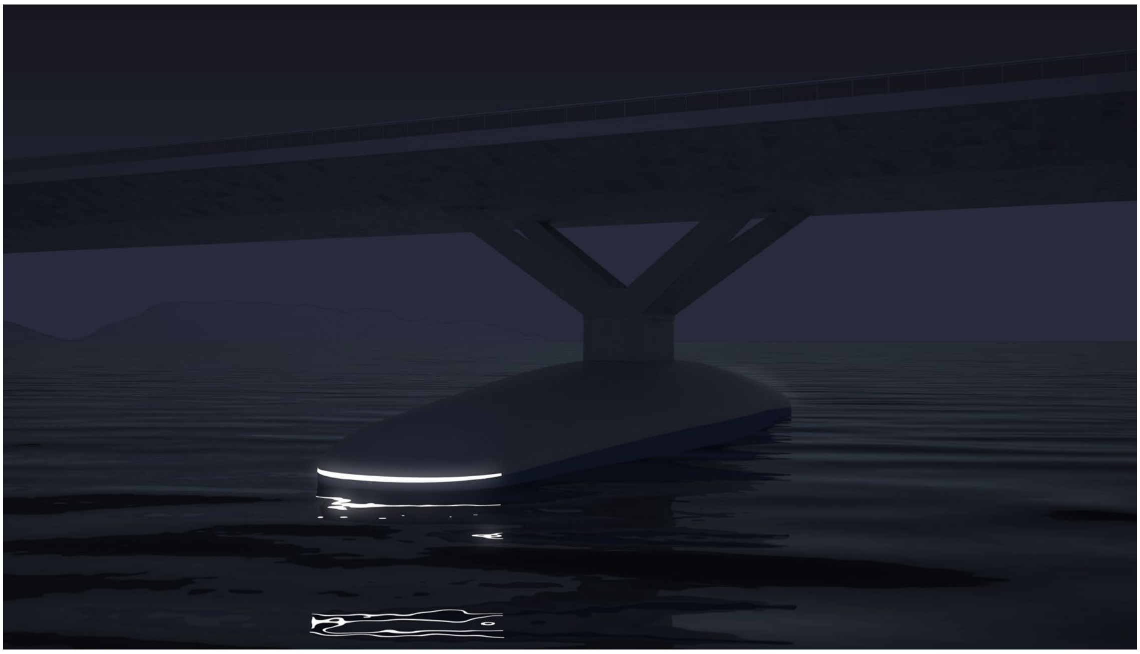
The options for lighting from the master that have been tried have unfortunately not been particularly successful. The luminaire has been placed low on the railing, and has provided glare for the driver in addition to the fact that the lighting is still visible from a long distance together with reflection on surrounding areas.

The only possible option is to reduce the requirement for a uniformly illuminated roadway. Thus, one will be able to illuminate only the outer edges of the roadway, illuminated by shielded luminaires from railings, on the sides and center parts. The area at the white road markings will then be illuminated, even after snowfall. The lighting will act as guide lines and show the roadway at a considerably longer distance than the car's own headlights can ever do.

It will be worth investigating this possibility because the architectural and environmental benefit is obviously large. The bridge itself is controversial and the traditional road lighting will not diminish the criticism. Light pollution in natural areas can be a problem, especially when touching as scenic surroundings as the Bjørnafjorden.
By reducing the general road lighting, one opens up the possibility of decor lighting on smaller and important parts of the bridge, -if wanted.

> *Figure 7-1: Reduced road light from edges only. Marking the white line at night.*

Environmental and light pollution considerations make it necessary to reduce the use of decorative lighting on the bridge. If you want to make use of decor lighting, it must be desired or combined with a functional use of lighting.
However, it is necessary to illuminate the shipping route and to mark the pontoons with warning lights.



> *Figure 7-2: Warning lights on pontoons*

> *Figure 7-3: Marking of the sailing route underneath the bridge*

During the day, the cable-stayed bridge will mark the sailing route. At night, this will be more difficult to perceive. It is therefore proposed to illuminate the cable-stayed bridge from underneath the girder. The solution will provide an illuminated roof over the sailing route. Two luminous stripes, one on each side of the bridge, define the sailing route under the cable-stayed bridge. In addition, the nearest column, tower and underside of the bridge path are illuminated.

> *Figure 7-4: Marking of the sailing route and the cable-stayed bridge, seen from the sea*

The cable-stayed bridge is the important iconic element for the bridge construction. It is possible to illuminating each cable. The lighting can be done with LED lights, which can be varied in all rainbow colors. This means one can change the temperature of the light, from warm to cold. A bundel of LED-lights can be mounted at the ends of the cables and are designed to shed light along the cables. In this way, the cables will form a luminous sail, visible through the night. If wanted, this will make the bridge a landmark even at night time. By using a photo cell in the tower, the evening's sunset can be recorded as a color temperature, so you can use this color in the led light that illuminates the cables . In this way one can get a subdued and balanced lighting, which gives the impression that the sunset "shines" in the bridge further out the evening.
One avoids a color that does not belong in the natural area and reduce the light pollution.
It could be a fascinating artistic, but at the same time a calm and no-disturbing effect.

8 FURTHER ARCHITECTURAL DEVELOPMENT OF THE PROJECT

It has previously been mentioned in this report that the landfall in the south can advantageously be moved to the east. This means that the tower is moved from the islet to the land side and that the landfall will remain behind the ridge and thus not visible from the strait. The horizontal curvature of the bridge remains the same. It is only a matter of a minor rotation of the basket towards the east. The landing point on the Gulholmen in the north is fixed.
Such a measure will significantly improve the K12 concept because it eliminates its only negative element. In addition, the recreation area at Skarvhellaholmen will remain untouched.
In our report, we have shown 4 possible solutions for pontoon and pillar. Option 2 is shown as an architectural adaptation to calculated and quality-assured engineering models. Architectural is a combination of options 1 and 3 preferable. We believe that a submerged pontoon has a significant potential. The argument against submerged pontoon has been focused on ship impact and "climbing" on a pontoon. Lately requirements regarding tonnage have subsequently been adjusted downwards. In addition, the column has been equipped with a weakness zone just below the rig. This means that in case of collision and any climbing, the column will be able to bend off before damage occurs on the bridge girder. By a ship impact the pontoon and the column will most certainly be damaged and be replaced. This can be done without damaging the girder. It is verified that a submerged pontoon, a “tripod”, fully carries the bridge. One argument against the solution is the climbing on to the pontoon. By the column and pontoon bending off, the climbing has been circumvented because the ship is at the same time slipping off. This means that this concept can be reviewed again.

> *Figure 8-1: Preferable architectural solution recommended for further development*

Model studies in 3D show that the submerged pontoon is far preferable architecturally. The solution opens up visually around the columns. This is in contrast to the surface floating pontoon which creates a continuous wall as seen along the bridge.

Along with the open rig at the top of the column, the solution with a submerged pontoon will give a maximum visual openness of the bridge path across the Bjørnafjord.
Architecturally, it is strongly recommended that this solution be further developed in the next phase of the project.