Transportation and Installation of a Marine Bridge

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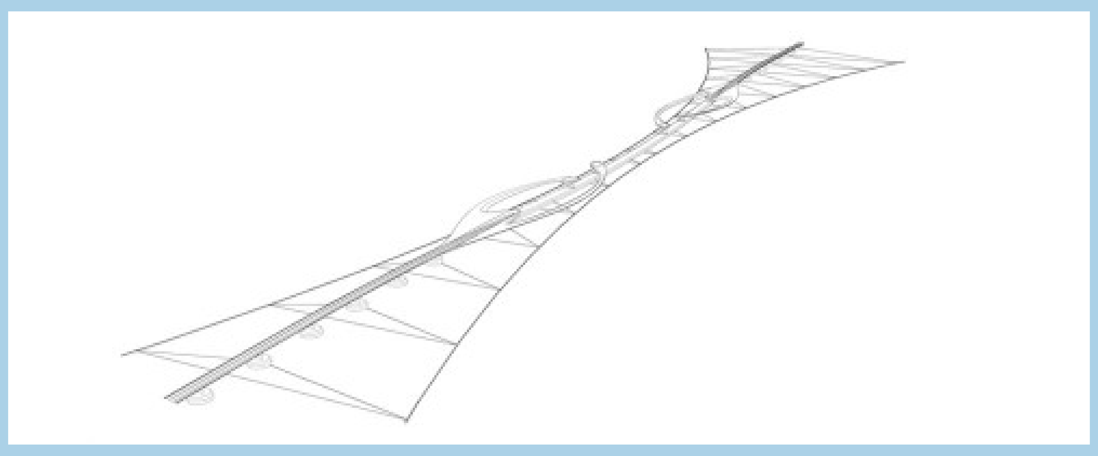
Introduction

The project "Ferry-Free E39" by the National Public Roads Administration aims to eliminate all ferries along the route from Kristiansand to Trondheim, in order to reduce the travel time with 10 h [2]. The fjords on this route are wide and deep, and conventional crossing methods with suspension bridges and bottom-supported bridges are not possible to use. Reinertsen has developed a new concept of crossing Sognefjorden [3]. The concept is divided into three main parts:

- Floating Bridge
- Submerged Floating Tunnel
- Artificial Sea Bed

The large depth of Sognefjorden makes anchoring infeasible, so an artificial seabed is developed to avoid this. DeepOcean is contributing to this project by assessing the challenges related to the artificial seabed, which can be seen below [3]. The longitudinal bundles of the artificial seabed are close to 4 km in length, and must be transported to the installation site. Additionally, the length of the bundles are longer than the width of the fjord, making installation challenging.



In this Master's Thesis, the transportation of the longitudinal bundles will be studied, as well as possible ways of installing the bundles without exposing them of critical loading.

Objective and Scope

The main objectives of this Master's Thesis are

- Analyze different stages of the towing of the bundle through Sognefjorden
- Find an approach for installing the bundle, and find the static and dynamic responses
- Conduct a parameter study of the towing and installation

Towing over the North Sea is excluded, due to this part being a well known procedure. The main aspects of the analysis will be feasibility of the operation and structural response of the bundle.

Methods

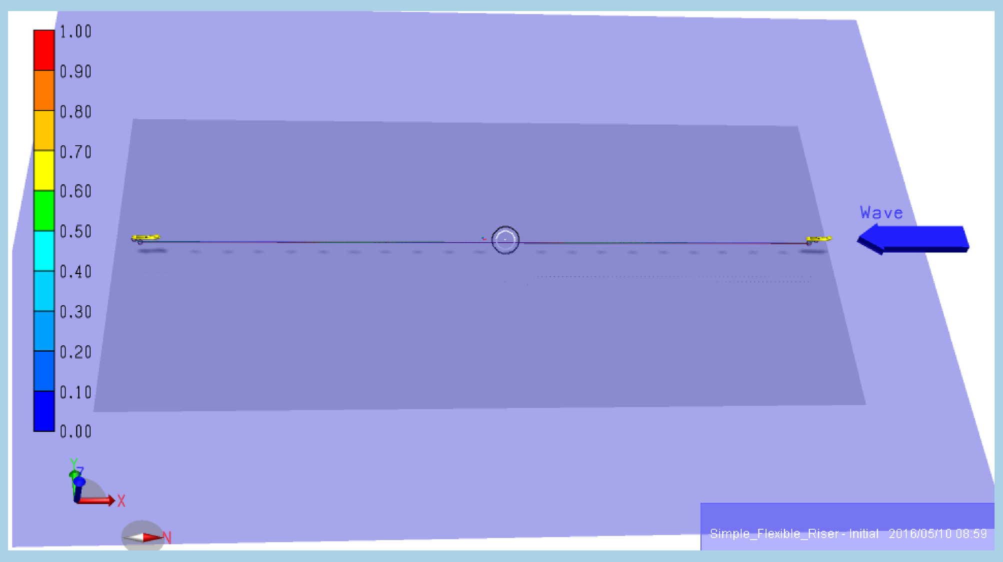
Sima Riflex, a computer program for analyzing slender marine structures [1], is utilized in this study. The three different analyses use the following theories:

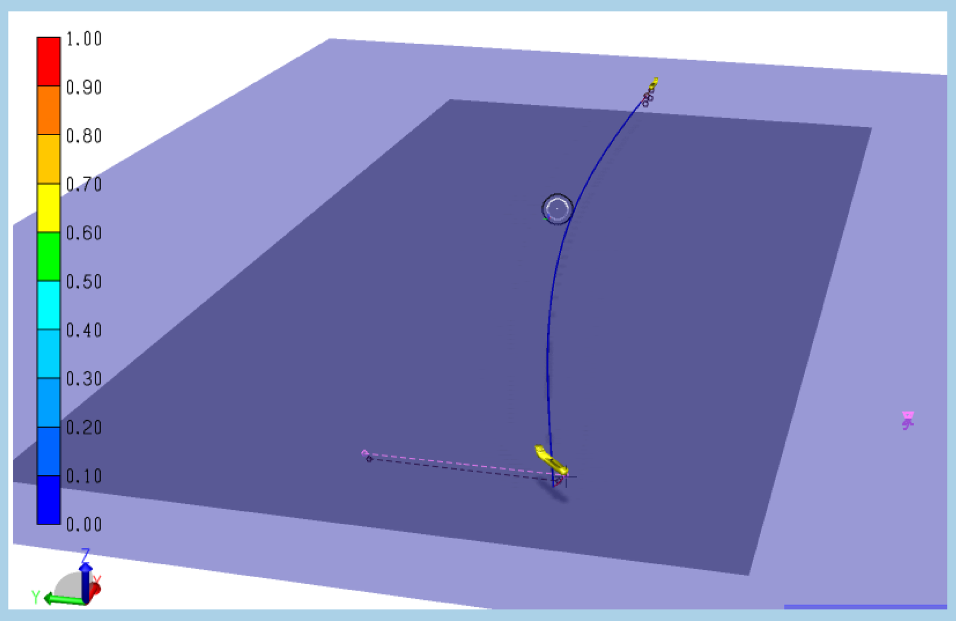
- Static Finite Element Method: Euler-Cauchy incrementation
- Dynamic Analysis: Nonlinear, linearized and frequency domain analysis
- Eigenvalue Analysis

Simulations

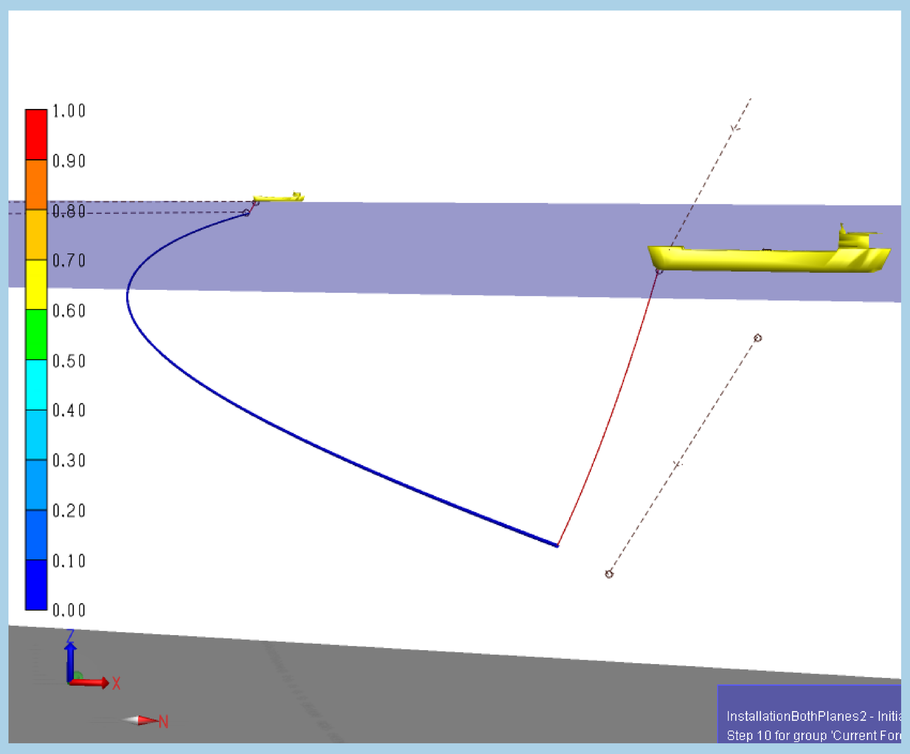
The model consists of a long, slender pipeline with towing lines connected at each end point. The towing lines are additionally attached to a towing tug. For the installation phase of the analysis, it was necessary to add additional weight to the bundle, which is simulated by NodalBody in Sima Riflex.

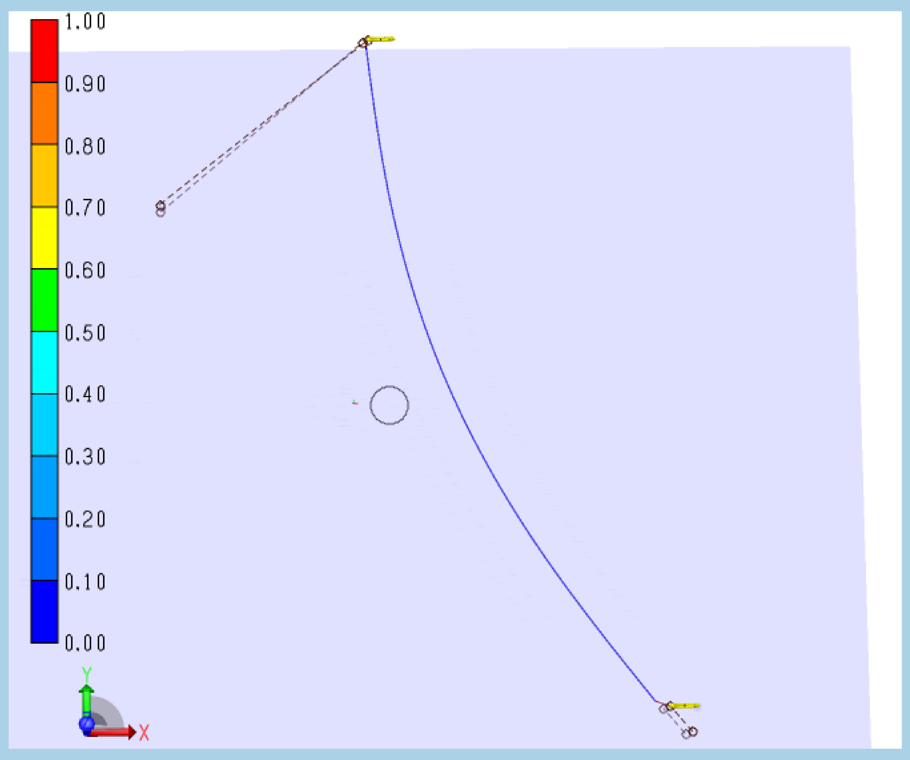
Both static, dynamic and eigenvalue analyses were run for both phases. For the towing of the bundle, the analysis was run for several environmental conditions, water depths and different degrees of bending of the bundle. The illustrations below show two phases of the towing; one with the bundle as straight and one with the bundle bent. For the last image, additional towing tug are simulated as point forces acting across the bundle.





Different approaches for installation were developed, considered and modelled. The chosen approach was modelled in several stages, enabling important details to be assessed. Additionally, a parameter study was conducted to check the systems sensitivity to bending. The images below show one possible installation seen from the ZX- and YX-plane.





Results

For the transportation of the bundle, the results revealed what sea states will give the most severe responses in bending moment. Additionally, it was found how much the bundle can be bent without adding severe bending moments.

For the installation of the bundle, the results revealed that torsional effects will be the most critical response. The appearance of large torsional moments comes from the bundle being situated sideways in the fjord, allowing current forces to affect the bundle from the side. Additionally it was found that when lowering parts of the bundle into the depth, the torsional moments increased even more. This is due to coupled effects between horizontal forces and torsional moments. (The details of the results are removed due to confidentiality)

Conclusions

The responses during transportation can not exceed the critical limit of yield stress which is set for the bundle. For installation it will be important to monitor the torsional moments due to current forces. Furthermore, by exploiting both the horizontal and the vertical plane, the bundle will be exposed for least bending and torsional moments. Three additional towing tugs are necessary when installing the bundle. (The details of the conclusion are removed due to confidentiality)

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References

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[2] Fjeld, A.: *Mulighetsstudie for kryssing av Sognefjorden - Neddykket Rørbru*, Technical Report, Reinertsen, Olav Olsen Group (2013)
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