Modelling and Analysis of a Floating Bridge

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Objective and Scope

The objective of the thesis work is to perform global response analyses on a floating bridge model which is to be modelled as a coupled SIMO-RIFLEX model in SIMA. The modelling should include:

- Hydrodynamic analyses of the pontoons in the diffraction theory solver in WADAM
- Modification and implementation of hydrodynamic results for the pontoons in SIMO
- Modelling the bridge structure and mooring lines in RIFLEX.
- Merge to a coupled SIMO-RIFLEX model

As part of this process focus is to be put on illustrating modelling limitations imposed by the software. Finally, relevant results are to be compared with result obtained by the NPRA and characteristic patterns in the response to be identified and described.

Introduction

The Ferry Free E39 project is led by the NPRA and has the purpose of improving the west coast main road. This will be done in terms of replacing the ferry connections by tunnels, cable-stayed bridges, floating bridges or submerged tunnels and upgrading parts of the existing road sections on land [1]. The goal is to reduce the travel time from todays around 21 hours to about the half, and has an expected cost of 340 billion NOK.

One of the proposed concepts for the Bjørnafjorden crossing is a straight floating bridge, which uses horizontal mooring systems to provide the required stiffness in the lateral direction. The bridge concept has a length of about 4500 metres, which almost doubles the length of the current world's longest floating bridge (2350 m)[2].

The bridge consists of a cable stayed bridge with a main span of 400 meter and a floating part supported by 18 equal pontoon, leading to spans of 203 meters. The average weight of a pontoon, including ballast, is about 14 000 tons.

Conclusion

From the analyses it can be concluded that the weak axis bending moments are dominated by the static response due to self weight for the governing wave direction, which is normal to the bridge. Therefore increasing the number of pontoons should be considered for the concept.

It is also evident that important information is lost due to the eigenvalue calculation limitations concerning the catenary mooring system. Further benchmarking should be performed.

References

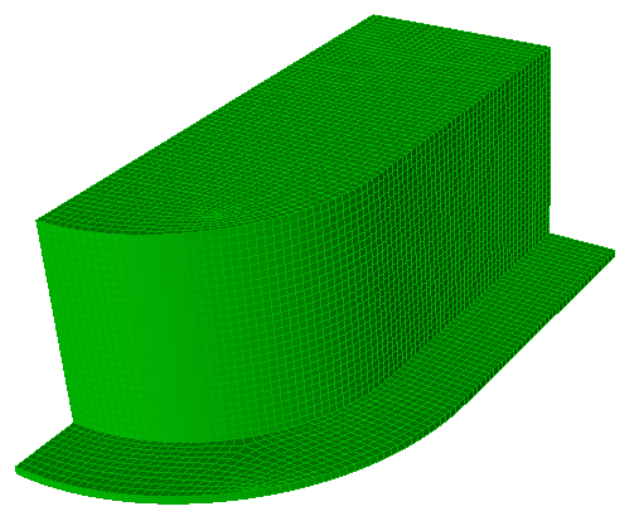
[1] https://www.vegvesen.no/en/roads/Roads+and+bridges/Road+projects/e39coastalhighwayroute

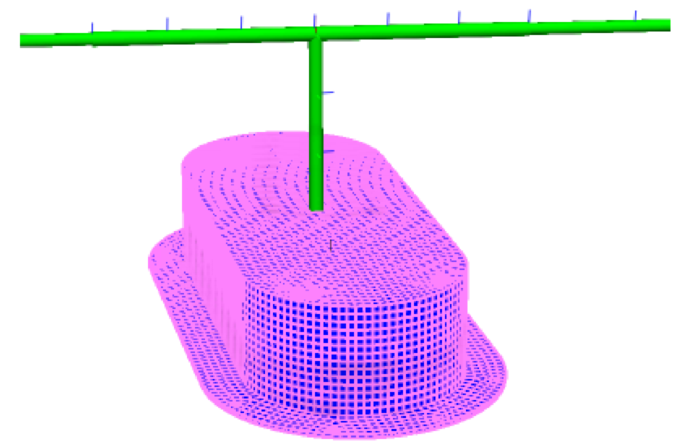
[2] http://www.wsdot.wa.gov/NR/rdonlyres/E1CE70E3-68E9-4C3B-90BA-00A12AF5955F/0/2017_0400_FBL_Booklet.pdf

Modelling

The first step in modelling the Bjørnafjorden straight bridge concept as a coupled SIMO-RIFLEX model was to perform a hydrodynamic analysis on the pontoon in order to provide input for the SIMO module in SIMA. A panel model of one fourth of the pontoon was made in GeniE and exported to HydroD. This panel model is seen in the top-left picture. The hydrodynamic analysis was performed in the frequency domain by use of potential theory in the module WADAM in HydroD.

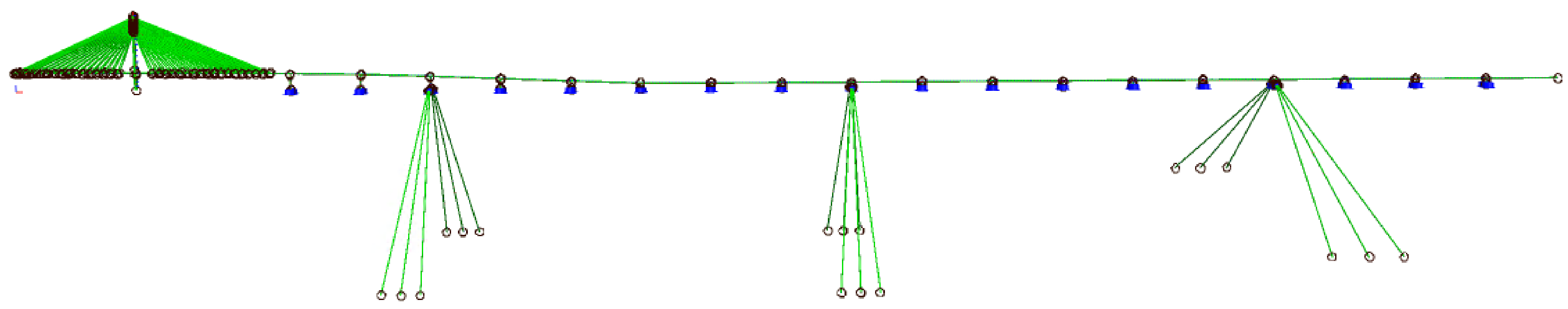
The hydrodynamic results were imported to SIMO. Some modifications of the non-frequency dependent results were performed in SIMO in order to account for the bridge structure and ballast, which were not included in the hydrodynamic analysis. The final hydrodynamic properties used by the SIMO module were the hydrostatic stiffness matrix, linear damping matrix, first order wave force transfer functions, retardation functions and added mass infinite frequency matrix.





The retardation function is used as a way of including frequency dependent added mass and damping in the dynamic analyses performed in the time domain. The infinite added mass is a matrix containing the added mass coefficients used in the eigenvalue analysis. This means that frequency dependent added mass is not supported in these calculations. However, the mentioned matrix can be changed manually by reading added mass coeffients from the results from WADAM.

The pontoons as implemented in SIMO are attached to the global bridge structure as seen in the top right picture. The complete bridge structure, including the cable stayed bridge, and the 18 mooring lines were modelled as slender elements in RIFLEX. The coupled SIMO-RIFLEX model is seen in the bottom picture.



Results

The eigenvalue analysis revealed significant limitations in the eigenvalue calculation code in RIFLEX, as it was seen that the catenary mooring systems were not properly included. By implementing the mooring systems in a linear fashion, the first 35 mode shapes and periods were coinciding well with those obtained on behalf of the NPRA.

The top figure shows the deformation of the bridge girder due to its self weight and a characteristic traffic load relative to its initial configuration. For the remaining plots the vertical grid lines goes through the girder-column intersections, except the first which goes through the tower. It can be seen that the drafts are increased with about 47 cm for the majority of the pontoons. In general, criterion on maximum static pontoon displacement poses restrictions on pontoon design, as it then requires a minimum water plane area.

The mid figure shows the strong axis minimum and maximum bending moments in the bridge girder for regular waves at several wave heights for a period of 6 seconds. The response is linear for small pontoon displacements.

The last figure shows the weak axis bending moments for regular waves with height 3 m and period 6 s for three wave directions respectively. Waves along the bridge impose pendulum motions of the pontoons for those connected to the higher columns, which lead to significant increase in the mentioned moments.