Hydrodynamic interaction among the pontoons of a floating bridge: effect on global responses

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Problem

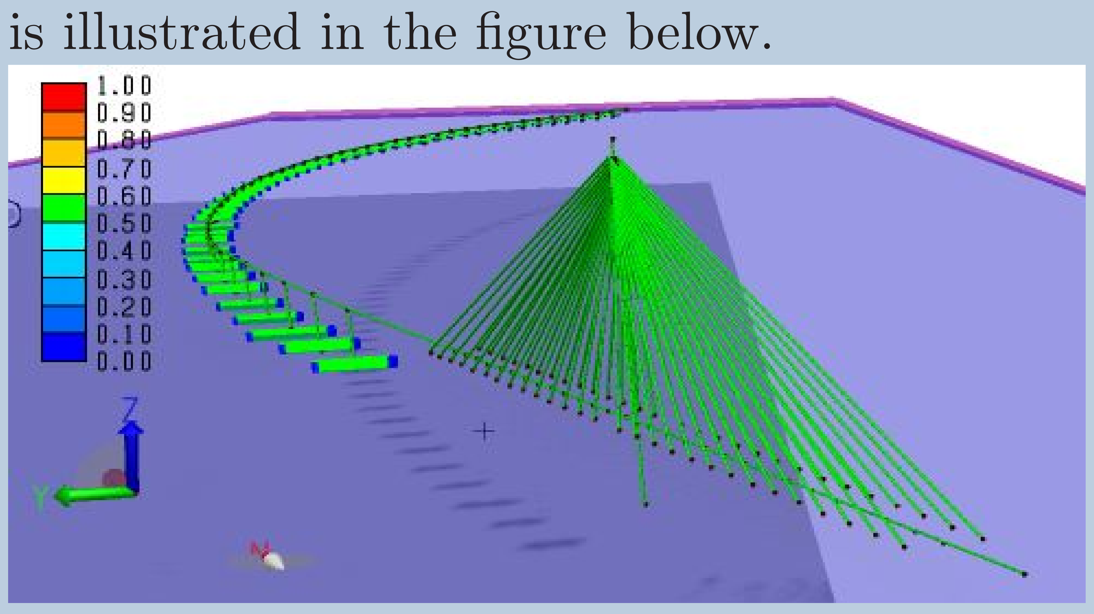
To improve the infrastructure between Kristiansand and Trondheim, the Norwegian Public Road Administration (NPRA) have ambitions of establish a continuous coastal highway, [1]. One of the fjords that has to be crossed is BjÃÿrnafjorden between Os and Stord. The length of this crossing is around 5 km and the water depth down to 550 meters. With this dimension it is impossible to solve with conventional bridge solutions. This project will be looking at a curved floating bridge design.

Objectives

- Potential flow analysis of two, three, four pontoon using Wadam.
- Examine hydrodynamic coefficients and compare to the coefficients for the single pontoon.
- Incorporate the hydrodynamic coefficients from Wadam in the simplified and global analysis models.
- Examine the effects of the hydrodynamic interaction on dynamic response in regular and irregular waves

Bridge Design

This project will be looking at the bridge design proposed in the report "Curved Bridge - Navigation Channel in South, developed in cooperation between COWI, Aas Jakobsen, Johs Holte As and Global Maritime. The bridge is floating freely without mooring lines and has a curved shape to carry shear forces by membrane action. The bridge girder have a total distance from south to north of 5435 meters. In the south end, a navigation channel are placed with a span-length of 525 meters. The low bridge have a span-length of 100 meters and the main girder is 16.2 meters above sea-level. The design is illustrated in the figure below.

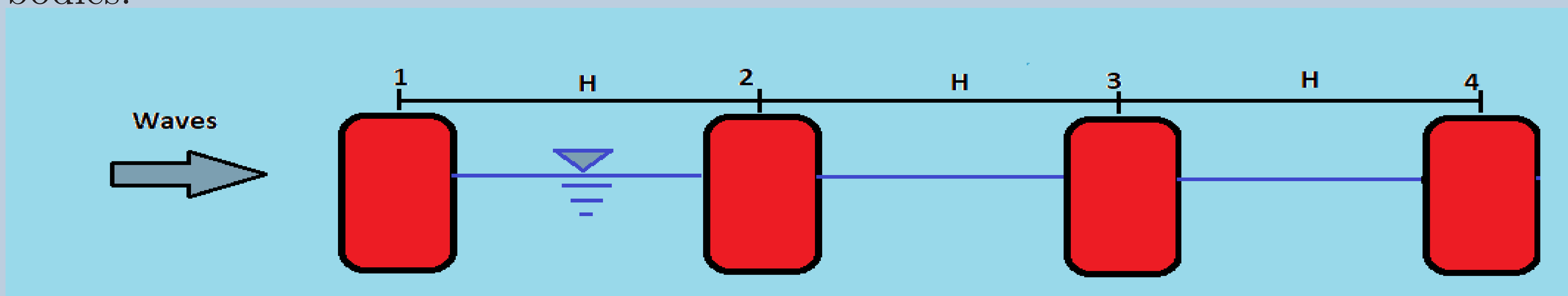


Method of analysis

The pontoon model was created in GeniE with a reasonable mesh. A first order potential flow analysis of different pontoons size in HydroD and WADAM. The curved bridge model was created in SIMA where hydrodynamic interaction between the pontoons were studied. Static analysis and eigenmode analysis was carried out to verify the model is modelled correctly. A simplified floating bridge was established to do further analysis of the effect of hydrodynamic interaction in different wave directions.

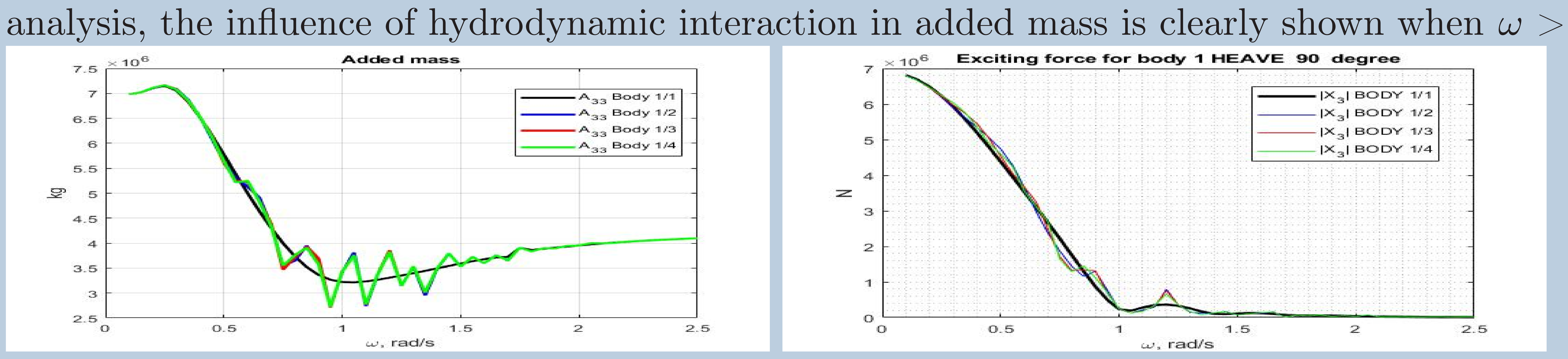
Hydrodynamic interaction

A simplified floating bridge was established to do further analysis of the effect of hydrodynamic interaction for different wave directions. Multibody analysis is carried out to see how the interaction effects the added mass, damping and excitation force. The spacing between the pontoons are 100 meters and wave direction 0, 45 and 90. The analysis have been performed in constant waterdepth of 500 m and waveperiod of 6s. The number of different bodies varies from one isolated body to four bodies.



Hydrodynamic Coefficients

Result for added mass and excitation force are present in Figure below. There are no difference in added mass for low frequencies in the multibody analysis. This is related to the relationship of the length of the pontoons and the corresponding wave length. For the comparison between single body analysis, the influence of hydrodynamic interaction in added mass is clearly shown when $\omega > 0.75$

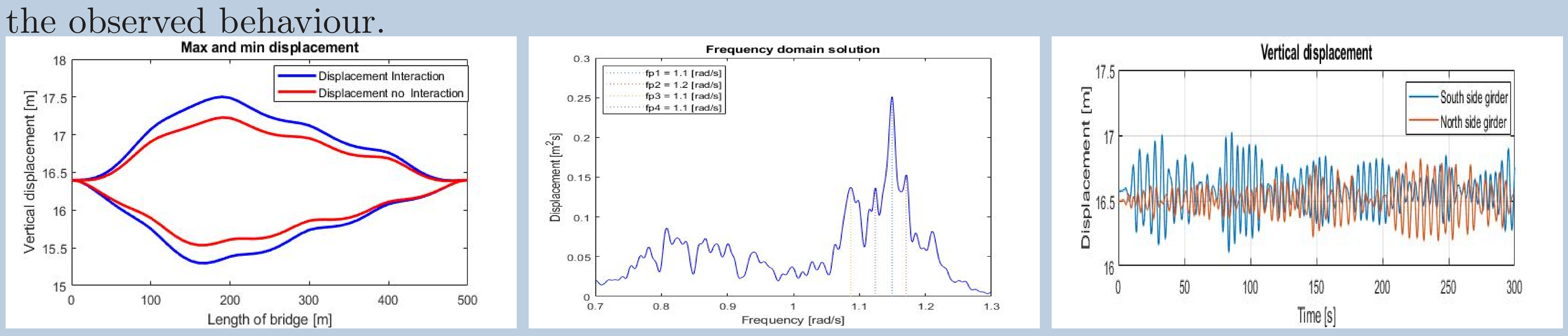


Results

The first figure illustrates the maximum and minimum displacement on each integration point during a 3 hours analysis. Comparing the results from the model accounted for hydrodynamic interaction the maximal and minimum displacement are larger than for the singel body analysis.

The frequency domain solution of the vertical displacement for the simple bridge is present in Figure 2. The vertical displacement is extremely irregular with sharp peaks at distinct frequencies. The largest peak at 1.15 rad/s, correspond to period of 5.5sec. This is close to the first eigenmode of 6 seconds which consist of vertical motions. This corresponds also to Tp=6 sec for this load condition

Figure 3 illustrates the vertical displacement for the north and south part of the bridge structure for a simulation length of 300 seconds. The motions of the bridge seems to follow a irregular displacement pattern. The irregular motions could be a result of differences in the geometry at the north and south part of the bridge. The difference in column height in addition to the high bridge will results in different stiffness properties for the two ends. The waves loads only act on the floating part, and the frequent of pontoons are higher at the north end, could also be a source of the observed behaviour.



Conclusion

It is no doubt that the floating bridge over BjÃÿrnafjorden is a very large and complex structure which requires expertise from many different disciplines. For the simple bridge, the vertical displacement are dominant for all wave conditions compared to horizontal displacement. When comparing the result from interaction of multiple bodies the maximum and minumum bending moment varies from wave condition to wave condition. The result from the multibody interaction have a larger respons for waves heading from the side.

References

[1] COWI: *Straight bridge - Navigation Channel in South*, 2016

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