Analysis and Design of Bjørnefjorden Floating Cable-Stayed Bridge subjected to Large Ship Collisions and Extreme Environmental Loads

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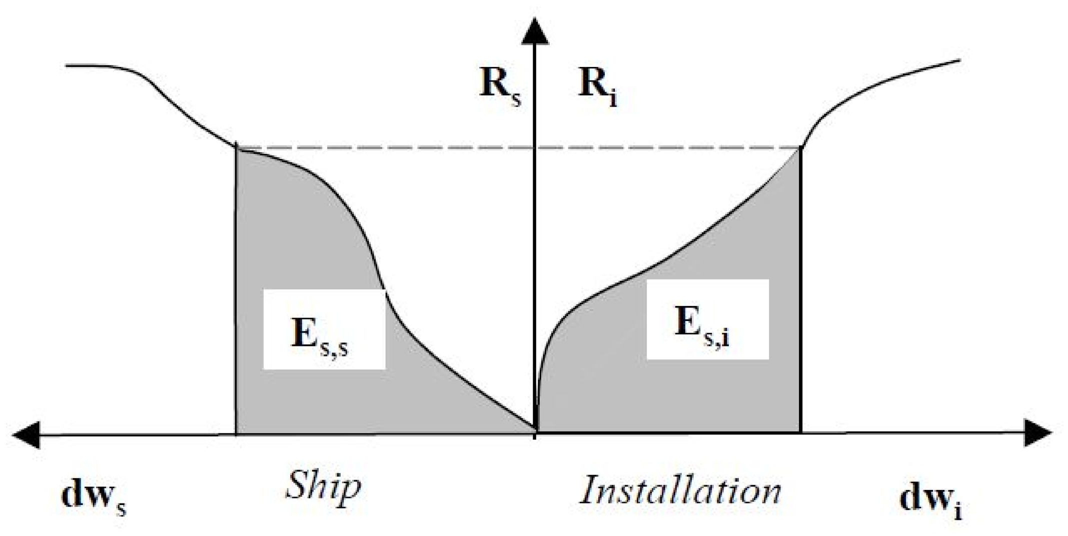
Introduction

- The objective of this master thesis is to study the global behaviour of the end-anchored floating bridge across the Bjørnafjord when it is subjected to ship collision and extreme environmental loads. The end-anchored floating bridge is one of the proposed concepts for the crossing of the Bjørnafjord, which is a part of of a national project, where the aim is to replace ferries with bridges and undersea tunnels. Due to the depth of the fjord, an undersea tunnel is not a good option. Consequently, a bridge is the only alternative for crossing the 5 km wide strait.
- According to the Norwegian Public Road Administration (NPRA), the crossing of the Bjørnafjord will be the longest floating bridge in the world, and existing design regulations are therefore not applicable[1]. Scenario-based analyses are therefore required in order to predict governing physical processes and to assess the capacity of the bridge to withstand them. In this thesis, USFOS will be applied in order to study high energy ship collisions, as well as extreme environmental loads.
- In this poster, the 1000 MJ collision between a 15 000 ton container vessel and the pontoon closest to the transit channel will be considered.

Theory

According to conservation of energy, the total energy after the collision is equal to the kinetic energy of the ship before it hits the pontoon. Some of the kinetic energy will be dissipated by local deformations in the ship hull and in the pontoon. This plastic deformation energy is referred to as strain energy. The total strain energy is given by the area below the force-deformation curve, see the figure.[2]



Method

The ship is modelled by a point mass with an initial velocity. An added mass of 10% is included. In order to account for the local deformation energy, the mass is connected to the bridge through a nonlinear spring that represents the force-deformation curve for the system. The shared energy principle is applied in the collision model, i.e. the strain energy in both the bridge and the ship bow is taken into account. The spring stiffness in tension is given a very low value in order to model the disconnection between ship and pontoon after the impact.

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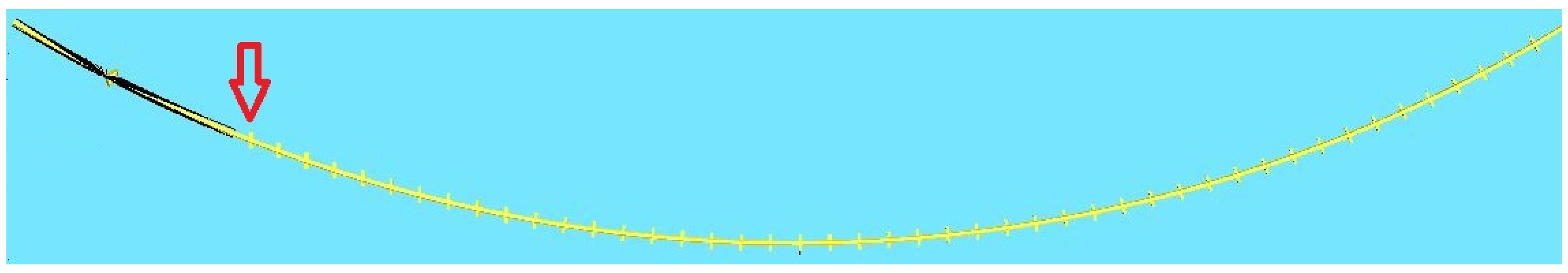
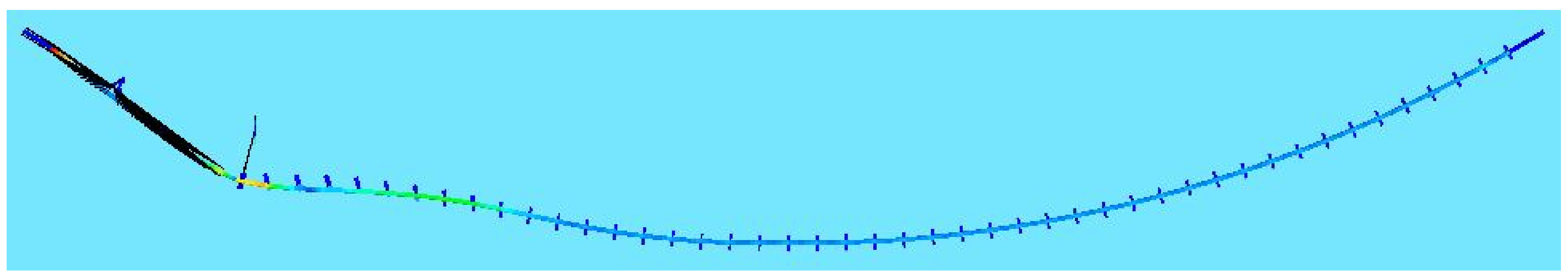
Description of the end-anchored floating bridge

The end-anchored bridge is curved in the horizontal plane, and has a total length of 5.5 km. The bridge is supported by 46 steel pontoons, which are placed 100 m apart. At the south end of the bridge, the bridge girder is elevated in order to serve as a transit channel for ship traffic. This is the cable-stayed section, where the bridge girder is supported by a 230 m tall tower. In the figure, the bridge is seen from above. The arrow indicates the location and direction of the ship impact.

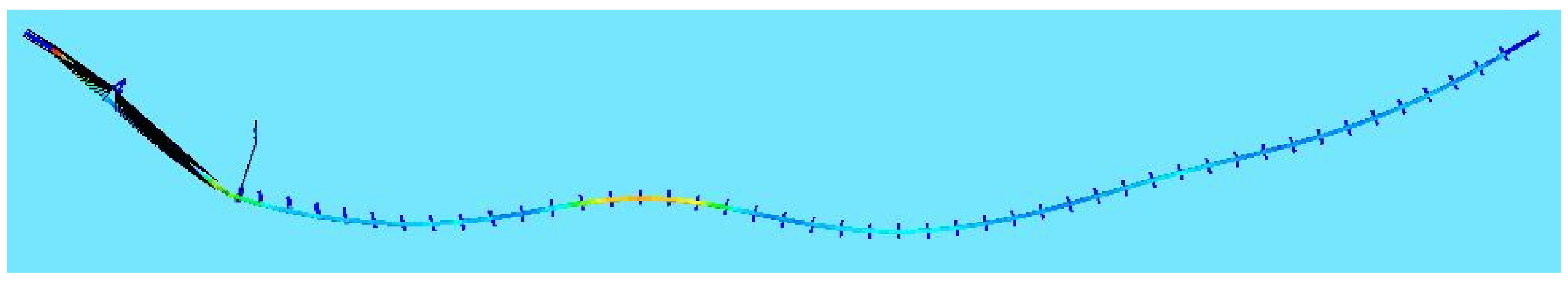


Results

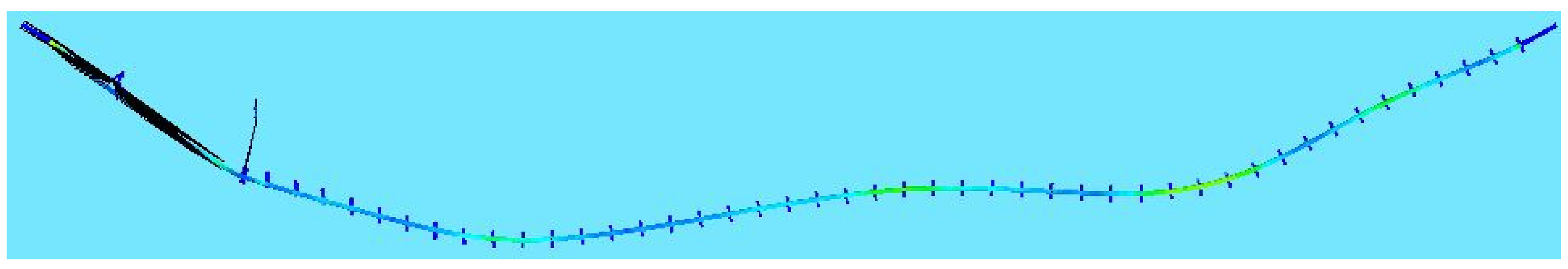
The bridge deformations caused by the 1000 MJ collision are given in the figures. For illustrative purposes, the deformations are scaled by a factor of 10. The colors indicate bending moment about the strong axis of the bridge girder.



(a) After 5 seconds



(b) After 14.2 seconds



(b) After 24 seconds

Strain energy	512.3 MJ	51.2 % of collision energy
Maximum bending moment in bridge girder		
Above struck pontoon	4700 MNm	153% of capacity
At end-anchoring	3800 MNm	124% of capacity

Conclusion

Bending waves are observed propagating away from the impacted area. The bending moment in the bridge girder above the struck pontoon gravely exceeds the capacity. This is also the case at the end-supports of the bridge. In conclusion, the 1000 MJ collision inflicts plastic deformations on both the struck pontoon and the bridge girder.

References

References

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[2] NORSOK. Norsok standard n-003 - actions and action effects. http://www.ivt.ntnu.no/imt/courses/tmr4195/literature/Standards2007. [Online; accessed 2-September-2017].