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Hydrodynamic load modeling and analysis of a floating bridge in homogeneous wave conditions☆

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ABSTRACT

The Norwegian Public Road Administration (NPRA) is currently developing the E39 ferry-free project, in which several floating bridges will be built across deep and wide fjords. In this study, we consider the floating bridge that was an early concept for crossing the Bjørnafjorden with a width of about 4600 m and with a depth of more than 500 m. The floating bridge concept is a complex end-anchored curve bridge, consisting of a cable-stayed high bridge part and a low bridge part supported by 19 pontoons. It has a number of eigen-modes, which can be excited by wave loads. Wave loads and their effects should thus be properly modeled and assessed. Therefore, the effect of hydrodynamic load modeling are investigated in homogeneous wave conditions, including varying water depth at the ends of the bridge, viscous drag force on pontoons, short-crestedness and second order wave loads. It is found that the varying water depth has negligible effect, while the other features are important to consider. Second order difference-frequency wave loads contribute significantly to sway motion, axial force and strong axis bending moments along the bridge. However, these effects can be reduced by viscous drag forces, which implies that an appropriate model of viscous drag force effect on the pontoons is important. short-crested waves greatly affect the heave motion and weak axis bending moment. All these considerations on hydrodynamic load modeling are further applied to analyze the wave load effect of a floating bridge in a fjord considering inhomogeneous waves [1].

1. Introduction

The Norwegian Public Road Administration (NPRA) is developing the European highway E39 ferry-free project, in which the deep and wide Norwegian fjords will be connected by bridges, instead of by ferries. Due to very large depth (up to 1300 m) and width (up to about 6 km) of these fjords, floating bridges are favorable from an economic point of view. The site considered in this study is the Bjørnafjorden located on the west coast of Norway, as shown in Fig. 1(a). It has a width of about 4600 m and a water depth in the middle of Bjørnafjorden of more than 500 m.

Several floating bridge concepts have been proposed for the crossing of Bjørnafjorden, including submerged floating tube bridge concept, cable stayed bridge with towers supported by TLP (tension leg platform) concept, side-anchored straight pontoon-supported floating bridge concept, and end-anchored curved pontoon-supported floating bridge concept [2]. Among them the end-anchored curved floating bridge concept is considered in this study, as shown in Figs. 1(b), 2 and 3. One main advantage of this concept is that

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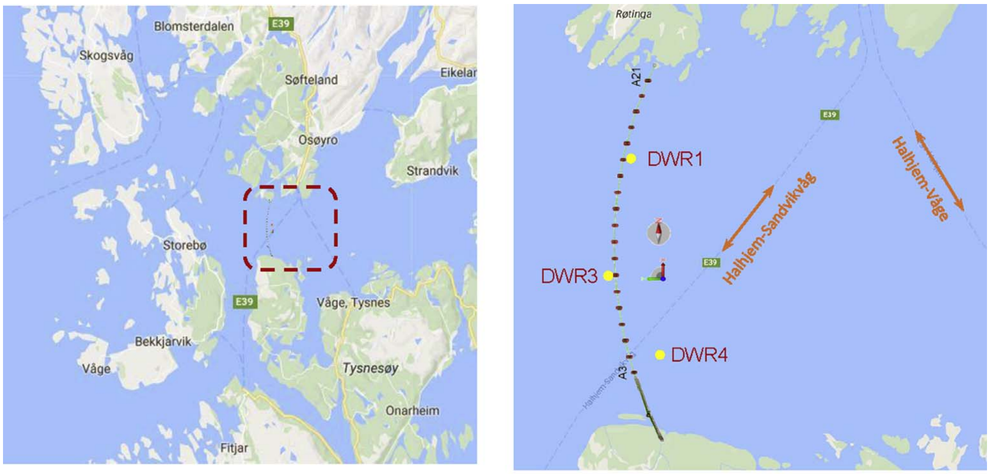

(a) The Bjørnafjorden (b) Floating bridge

Fig. 1. (a) Potential site for a floating bridge in Bjørnafjorden. (b) An end-anchored curved floating bridge model across the Bjørnafjorden. The approximate position of three Datawell Directional Wave Riders (DWRs) is also marked.

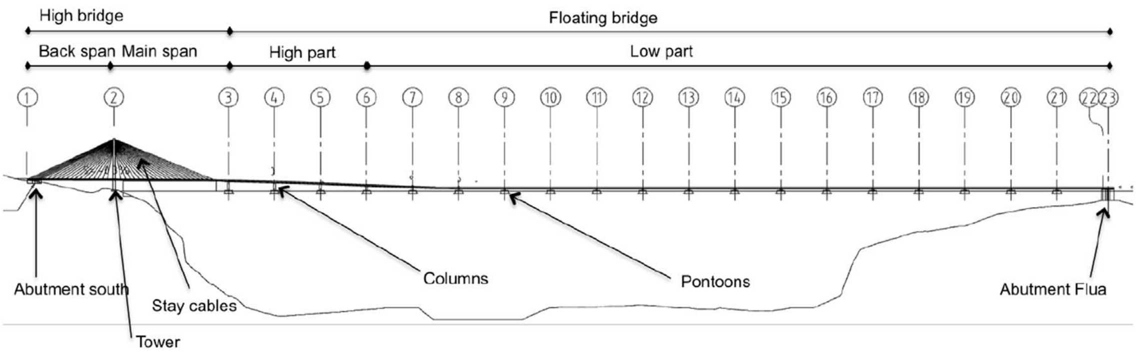

Fig. 2. The end anchored curved floating bridge concept [13].

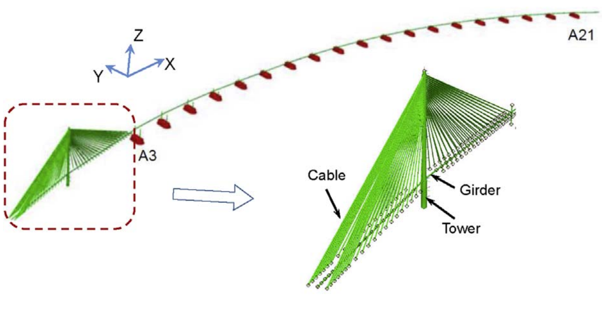

Fig. 3. The end anchored curved floating bridge model including a cable stayed high bridge and a pontoon supported low bridge.

it avoids the use of mooring system in deep water, since it can carry transversal loads through arch action. Currently there are two existing floating bridges in Norway, i.e. the Bergsøysund bridge close to Kristiansund, and the Nordhordlands bridge North of Bergen. Both these two bridges adopted the curved, end-anchored design.

The floating bridge supported by pontoons is a kind of Very Large Floating Structures (VLFSs). Hydroelastic behavior of VLFSs has been numerically investigated by many researchers. Three approaches are usually used for hydroelastic analysis of VLFSs, i.e. the modal superposition method [3–5], the direct method [6], and the discrete-module based method [7,8]. In addition, several studies are especially carried out to investigate dynamic responses of floating bridges in fjords. Based on the multi-mode theory, Kvåle et al. [9] developed a method in the frequency domain to account for the hydroelastic responses of pontoon type floating bridges, and applied it to investigate the dynamic behavior of Bergsøysund bridge. Lie et al. [10] investigated the feasibility of deploying an end-anchored floating bridge in Masfjorden and compared its dynamic response with a submerged floating tube bridge concept.