Adaption of estuarine waterway infrastructure to mitigate the effect of long-period ship-induced waves.

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MOTIVATION

In narrow maritime channels frequented by large vessels, particularly in estuaries serving as entryways to seaports, the impact of waves generated by ships has grown increasingly significant. This is mainly due to the continuous enlargement of vessels in operation. Of notable importance is the potential for increasing damage associated with the extended wavelength of the long-period primary wave system, which distinguishes it from natural hydrodynamic forces (Dempwolff et al., 2022a). Due to this unique characteristics of ship-induced primary waves, the damage mechanisms acting on the estuarine infrastructure can be specific to long-period ship-induced waves (Dempwolff et al., 2023b). Examples of civil works being deteriorated by primary waves are rock groins which are overtopped during ship passages, as shown in Fig. 1. This leads to a displacement of the armour layer near the groin root. Consequently, this study aims to explore possible mitigation strategies that can be employed to reduce the loads on estuarine groins.

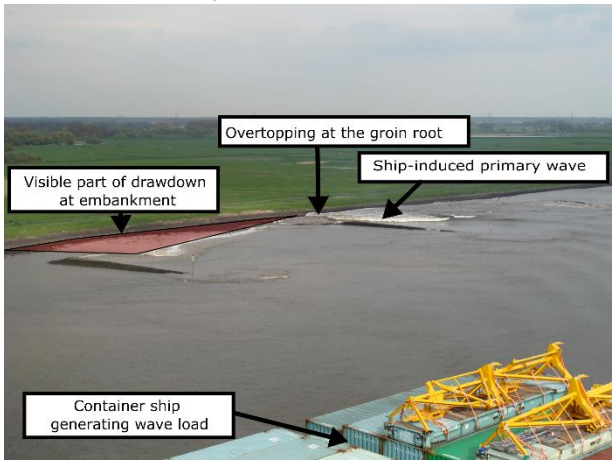

Figure 1 Photograph of ship-induced groin overtopping from a container ship. Source: BAW

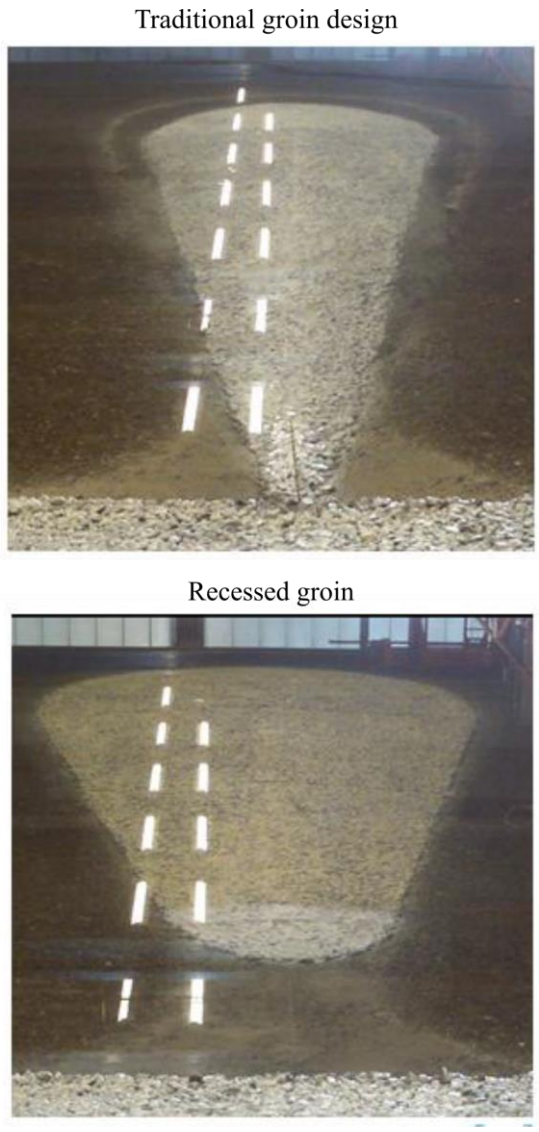

Figure 2 Scaled models of different groin designs. (BAW, 2015)

METHODS

Within the hydrodynamic modelling toolbox REEF3D, a novel multi scale simulation approach to predict the hydrodynamic flow field around an estuarine groin has recently been presented (Dempwolff et al., 2023a). The approach makes use of a novel coupling interface between the two open-source solvers REEF3D::SFLOW (Wang et al., 2020) and REEF3D::CFD (Bihs et al., 2016). REEF3D::SFLOW is a shallow-water-equation

solver that has been extended with a free surface pressure term to represent ship wave generation (Dempwolff et al., 2022b). Simulation results of a ship passage in a confined waterway are then imposed to a simulation with REEF3D::CFD. This solver makes use of the Reynolds-averaged-Navier-Stokes equations and is therefore suitable for the simulation of small scale near bank processes in three dimensions. Real-world prototype constructions suggest that the damage potential of ship-waves acting on these estuarine groins can be reduced by employing adapted geometries, including modified construction slopes and a gap between the groin and the adjacent embankment (Melling et al., 2020), such as shown in Figure 2. However, no optimization of the design could be performed, due to the costs associated with the construction of real-world prototypes. Numerical modelling with the coupled REEF3D framework can fill this knowledge gap, providing the possibility to examine different geometric configurations and their impact on the hydrodynamic flow field around estuarine groins.

RESULTS

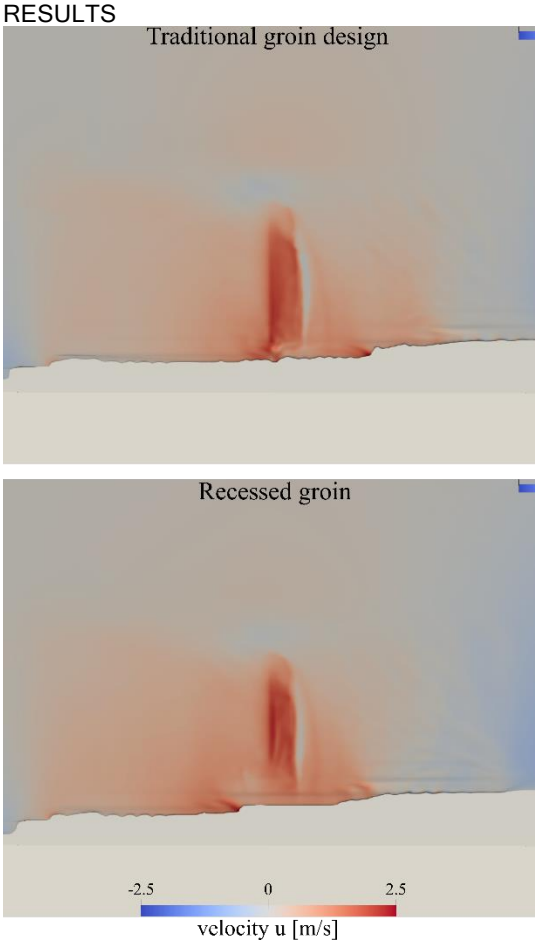

Figure 3 Numerical simulation results for the velocity normal to groin orientation. obtained with the coupled REEF3D:SFLOW-CFD model.

Figure 3 indicates the velocities in ship motion direction, during the passage of a critical design ship. The simulation of the overtopping process with the coupled numerical model indicates a significant reduction of the velocity near the groin root, consequently reducing the structural loads and the damage potential in this most vulnerable part of the groin. The possibility to explore the complex relation of ship parameters and structural loads hence provides the means to optimize the groin design to make it resistant against the deteriorative loads induced by long-period ship-induced waves.

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