Technische Universiteit Delft

Offshore & Dredging Engineering

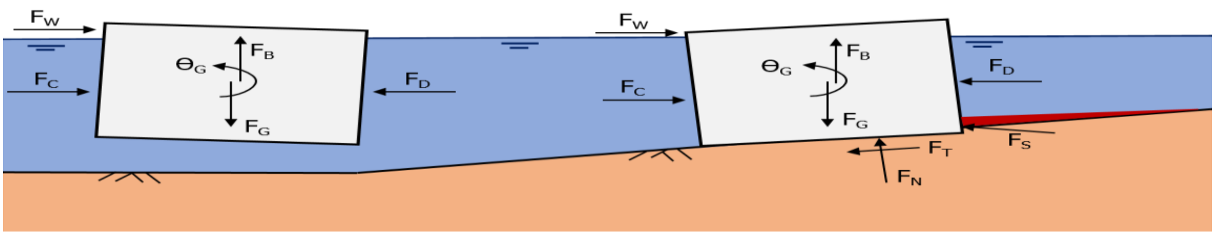
Dynamic simulation of seabed gouging by icebergs

In the Arctic, it is especially attractive to transport hydrocarbons by means of marine pipelines as this largely prevents the interaction with sea ice. Nevertheless, icebergs and ice ridges are a danger to marine pipelines when they ground and gouge the seabed. Generally, marine pipelines in iceberg areas are buried in a trench to protect these pipelines from damage due to iceberg gouging. As it is not economically feasible to bury these pipelines at depths where soil deformations are negligible, these pipelines must be buried at depths where the soil experiences significant deformations. Understanding the severity of these sub-gouge soil deformations is vital for offshore pipeline design and in particular to determine the required depth of pipeline trenches.

In the past, several models have been developed to describe the interaction forces between an iceberg and the soil in front of the iceberg keel. The majority of these models is based on experimental observations. These models do not properly account for the dynamic behaviour of the iceberg; either the iceberg velocity is assumed constant during gouging, or the gouging path is pre-described. Therefore, a two-dimensional model is developed that describes both the free-floating behaviour of the iceberg, properly accounting for the hydrodynamics of the iceberg, as well as the interaction of the iceberg with the soil as it grounds. Plane-strain conditions are assumed for the soil and the iceberg itself is assumed as a rigid body. Results for the model are presented for various iceberg shapes and soil characteristics and compared to data from full-scale experiments available in literature.

In this thesis, in particular, the dynamic effects are investigated of i) icebergs in water and ii) icebergs interacting with the seabed. The two-dimensional modelling is therefore divided into two parts; the water-iceberg interaction and the iceberg-soil interaction. In the water-iceberg interaction model, first the hydrodynamics of a free-floating iceberg are described. Subsequently, the iceberg is considered in a continuously decreasing water depth until, eventually, it collides with the seabed. Then, the iceberg-soil interaction model describes the iceberg as it gouges the seabed, both for a rigid seabed, as well as for real soil conditions. Here, the interaction with the rigid seabed is considered to determine the extremes of dynamic iceberg behaviour.
Results from the water-iceberg interaction model show that icebergs in equilibrium conditions are not significantly affected by a significant increase of added mass in heave direction. Since the heave velocity of the iceberg in equilibrium conditions is nearly equal to zero, the corresponding heave added mass coefficient hardly affects the motions of the iceberg.

To obtain results for the iceberg-soil interaction model, three types of soil are considered: rigid soil, sand and clay. As the iceberg cannot penetrate the rigid seabed, icebergs in rigid soil decelerate exclusively by the normal force and the resulting Coulomb friction, resulting in an overestimation of the gouging lengths. For the non-rigid seabed, iceberg gouging is mainly affected by passive soil forces in front of the iceberg and the bearing capacity of the seabed soil. The parameters that have a large impact on the gouging process are iceberg shape, iceberg mass, soil slope angle and soil strength. For the seabed with real soil conditions, the influence and sensitivity of these parameters are analysed. An increase in soil strength results in less soil penetration of the iceberg. Variation in iceberg shape results in significant changes in soil penetration and gouge length.



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