DEVELOPING A COMPUTATIONAL FLUID DYNAMICS (CFD) MODEL FOR EMBANKMENT DESIGN

Modelling ship propeller propulsion impact on Bubendey embankment

The Hamburg Port Authority (HPA) is responsible for the management of the Port of Hamburg and is therefore also responsible for maintenance and construction of embankments. For the repair and construction of embankments, a standard procedure developed by the German Federal Waterways Engineering and Research Institute (BAW) – 'Principles for the Design of Bank and Bottom assurance on Inland Waterways' (GBB) – can be used. However, the applicability of the GBB in the area of sea ports and maritime waterways is limited. It leads to very conservative results compared to in-situ measurements. DHI was therefore commissioned by the HPA to develop a more accurate method for estimating the relevant parameters, which is transferable to other ships and embankments. We chose a three-dimensional Computational Fluid Dynamics (CFD) flow model to solve this problem. The CFD model was calibrated and validated with on-site measurements. Furthermore, a comparison with the GBB procedures was performed.

CLIENT

Hamburg Port Authority

CHALLENGE

- Verification of flow velocities on the embankment due to propulsion
- Model transferability to other sites

SOLUTION

Setup of a generalised CFD model which allows an easy switch to calculate different embankment load scenarios

VALUE

- Safety-suited design by taking into account the exact embankment layout
- Cost savings during embankment repairs or construction
- Sustainability and conservation of resources

LOCATION / COUNTRY

Hamburg, Germany

DATA COLLECTION

A measurement frame was installed at the Bubendey embankment in the Port of Hamburg, containing three sensors for each horizontal velocity component and 16 pressure sensors from DHI Sense. The tug 'SCHLEPPKO 7' was moored to a pontoon and to the embankment to minimise yaw, roll and pitch, ensuring that the propeller jet pointed directly towards the measurement frame on the

Experimental setup at the Bubendey embankment (Hamburg, Germany), September 2014. © DHI embankment. The measurement campaign lasted one week. Several configurations of water level, applied engine power and rudder angle were set up.

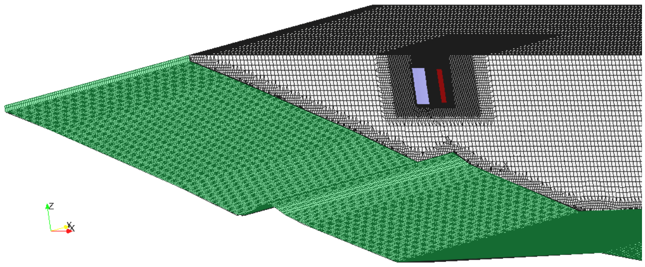
CFD MODEL

The generalised description of the predominant natural conditions was given special attention, in order to obtain a CFD model that is relatively simple and inexpensive to be transferred to other embankment and ship scenarios. It bases on the CFD package OpenFOAM®.

Comparative studies of several propeller jet spreading models show that the momentum source model sufficiently describes the tangential and radial moments as well as the impact of the rudder blade on the propeller-induced velocities on the embankment.

The momentum field of the propeller is crucial for determining the representative velocities on the embankment. It can be described by a set of coefficients. The rudder blade has to be taken into account, since it has essential influence on the propeller jet propagation by dividing and redirecting the propulsion jet. The exact geometry of the propeller and the ship hull was not represented, as these are insignificant for the propeller-induced flow on the embankment.

The area represented in the model was 60 m wide and 85 m long. The computational mesh was resolved very high in the region around the rudder and the momentum source field. On the surface of the embankment, a higher mesh resolution was imposed as well. Overall, the computational mesh included more than three million elements.



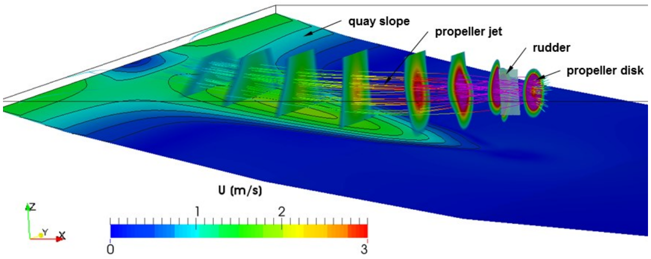
Section through the computational mesh of the Bubendey Quay. © DHI

For the description of the propulsion jet emanating from the propeller disk, very few parameters are required; such as propeller diameter, number of revolutions and applied engine power. Each mesh element within the propeller disk was assigned a coefficient that was derived from the mentioned propeller properties.

The model was calibrated using the measurements which have been derived from the event during which 50% of the maximum engine power has been applied. The validation was successfully carried out using the 25% as well as the 70% measurement event.

RESULTS

The comparison of model results with measured data shows that the CFD model provides conservative values and is therefore suitable to support embankment design. However, the model results are approximately 30% below the values determined by the GBB process, which qualifies the CFD model as an economic planning alternative for selecting the embankment protection.

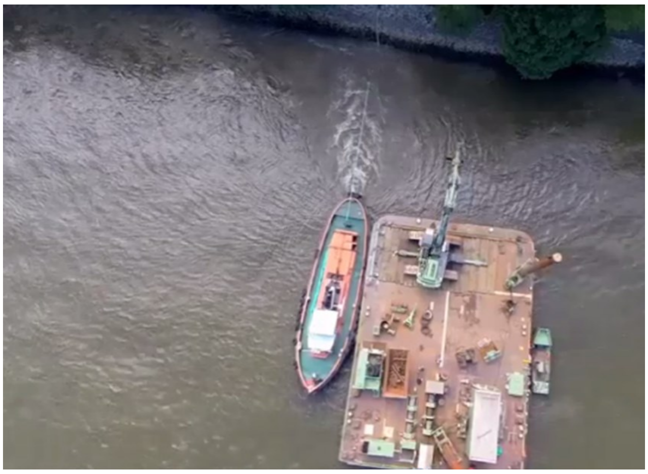


3D model result presentation for 70% engine power. The rudder is drawn transparent. © DHI

CONCLUSION

This study has shown that the CFD model delivers reliable results that are conservative enough to sustainably and cost -effectively dimension the embankment protection. It led to approximately 30% lower velocities on the embankment.

The CFD model is able to take into account any slope situation (including berms, sheet pile walls and so on) and is applicable for maritime waterways and seaports. The scalability of the CFD model allows the calculation of the embankment load for various port and ship dimensions. Thus, the CFD model is already a suitable tool in the planning phase. Due to its variability to represent the local conditions in detail, it can provide design parameters which lead to more economic constructions and a reduction in maintenance costs.



Aerial view of the Bubendey Quay during the measurement campaign. © DHI

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