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PHYSICAL MODELLING OF PROPELLER JET INDUCED SCOUR NEAR QUAY WALLS

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ABSTRACT

Ship propellers cause high flow velocities near quay walls, jetties, locks and other hydraulic structures which can lead to scour of the bed near these structures and potentially result in instabilities of the construction. Bed protection is commonly applied as a measure to prevent damage and increase the life span of such hydraulic structures. When designing bed protection, the existing guidelines e.g. (PIANC 2015, BAW 2010) may not always result in optimal designs due to simplifications made in jet-flow schematizations and uncertainty of propeller-induced loads. To improve these design guidelines and optimize bed protection, a working group led by CROW (a knowledge platform in the Netherlands on infrastructure and mobility) and the Dutch Government was formed, and a joint research programme was initiated aiming at developing knowledge on propeller jet-induced scour by combining field measurements (Tukker 2021), scale model tests (Deltares 2023), and numerical modelling. The objective of the presentation during the Coastlab24 conference is to provide an overview of the various measurement techniques applied in the present research.

The research includes a physical scale model built at Deltares to investigate the flow patterns generated by confined propeller jets induced by a large inland vessel (see model vessel in Figure 1, top). The study involves the utilization of Particle Image Velocimetry (PIV) to characterize in high detail propeller jet-induced flow fields (see middle left of Figure 1), near-bed velocities, and turbulence levels. PIV measurements were performed for both conventional *rip-rap* bed protection and for rock-filled mattresses specifically designed for underwater applications, a new system as developed by Maccaferri S.p.A.

In addition to the analysis of the flow field, the deformation and stability of the rock-filled mattress system was quantified using stereo photography measurements (see middle right of Figure 1) and the dynamics of the mattresses during propeller-induced loading were monitored with accelerometers (see bottom left of Figure 1). Scaling of the mattresses was performed to ensure a similar behavior between prototype and model, with focus on relevant parameters such as bending stiffness, roughness, and permeability of the geotextile.

Other measurement techniques and equipment used includes force transducers connected between the vessel and the vessel support structure to measure the mooring forces. An acoustic flow meter was present in the bow thruster channel to verify the jet bulk velocity. Also, several electromagnetic flow meters were installed on the bed during tests with a smooth bed to verify the near-bed velocities measured with PIV. Furthermore, the propeller rotation rate was measured during all tests.

Additionally, during the test campaign the application of alternative PIV seeding material was investigated. Conventionally, small solid spheres (glass or polyamide) are used as tracer particles for PIV measurements at the Deltares facilities. However, the addition of these particles in the experimental facilities can lead to long lasting contamination of the facilities and its water reservoirs. Moreover, cleaning the water and facilities of these microplastics- especially for large experimental setups - leads to high costs. As an alternative for these solid particles, seeding with hydrogen bubbles, generated by electrolysis of water was tested. In-house made, flush electrolysis generators were mounted on the model floor to form electrolysis bubbles downstream of the inflow of the propeller (as is depicted on the bottom right of Figure 1).

From the scale-model tests a better understanding of the mechanisms behind propeller jet induced scour is obtained, improving bed protection strategies, and thereby contributing to the resilience and stability of quay walls.

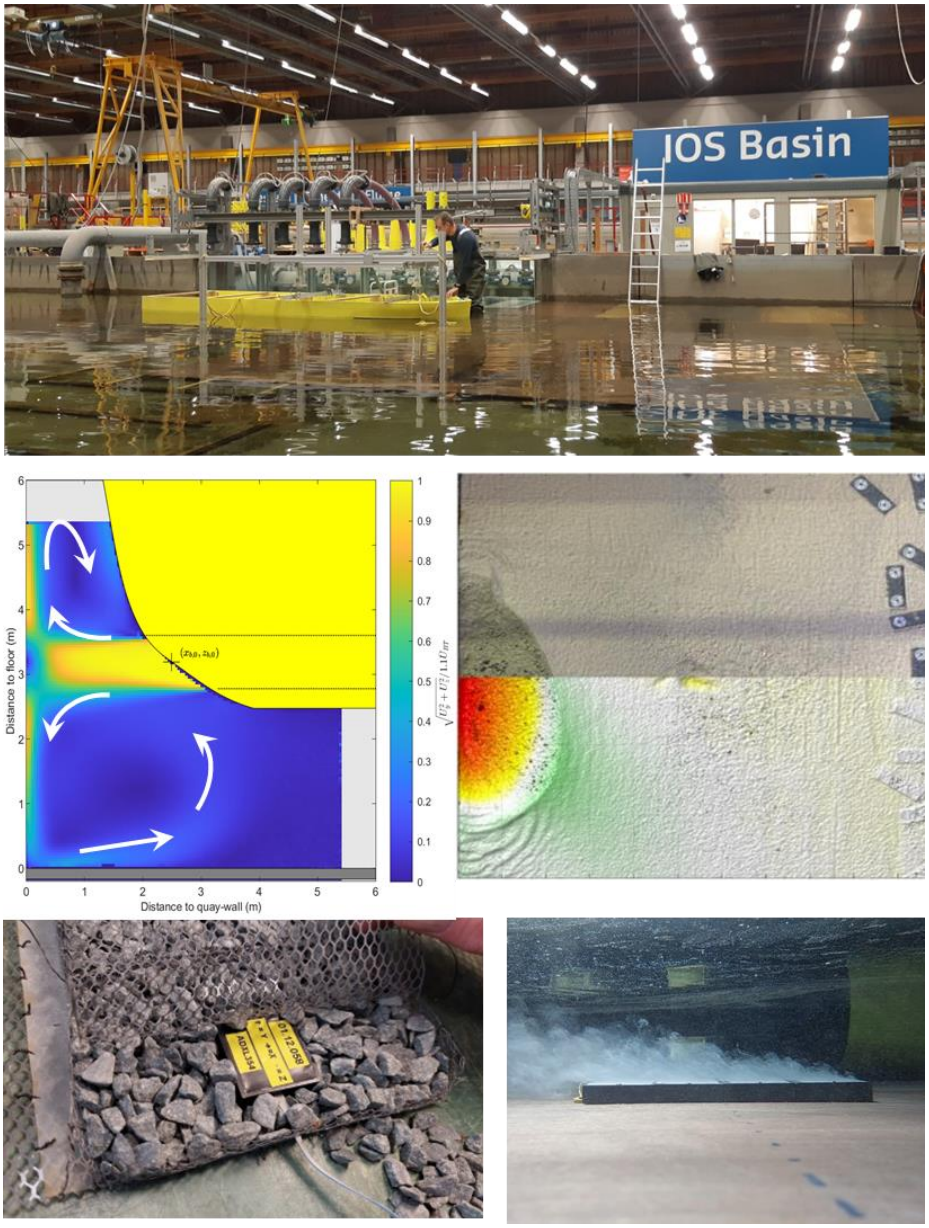

Figure 1 - Top: model vessel being maneuvered in place by lab technician. Middle left: flow field generated by bow thruster jet and obtained from PIV measurement. Middle right: 3D bathymetry from stereo photography measurement. Bottom left: accelerometer built into a rock mattress to capture motions. Bottom right: hydrogen bubble generator as alternative to conventional PIV seeding.

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