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Estimation of open channel bathymetry with video images from surface data

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ABSTRACT

This work aims to investigate the reliability of a methodology used for determining bathymetry near seaports through the capture of sea surface images using a video camera in a laboratory channel conducting small-scale experiments. Regular waves are propagated in a fixed horizontal bottom, considering different wave heights and periods. The best results, obtained for the shortest periods and highest wave heights, demonstrate the methodology's usefulness in the laboratory.

1. Introduction

Coastal areas, especially those with significant sediment transport, undergo substantial changes in bottom morphology during stormy seasons. Adverse sea conditions make in situ bathymetry monitoring challenging with conventional methods, necessitating alternative solutions. Remote bathymetry detection emerges as a viable option, overcoming limitations imposed by adverse weather and energetic waves. Santos et al. (2022) distinguish between two remote sensing approaches for shallow depths based on imagery. The first relies on the seabed interaction with light radiation, suitable for transparent waters with low turbidity. The second, employed in this study, uses surface wave characteristics to estimate local depth.

2. Methodology

Experiments were conducted in a horizontal wave channel at the hydraulic laboratory of NOVA School of Science and Technology | FCT NOVA. The channel, 5 m long with an 8.2×25.0 cm² rectangular cross-section of acrylic walls, utilized a piston-type wave maker and a video camera for recording propagating waves. Image orthorectification and timestacks creation followed image acquisition (Umberto, 2019). Bathymetry was inferred based on wave patterns detected in the timestacks, following Santos et al. (2022). Tests covered water depths (h) from 6.8 to 15.2 cm, varying wave heights (H) between 1.7 and 4.0 cm, and wave periods (T) between 0.79 and 1.79 s.

3. Results and discussion

Fig. 1 displays a picture of the experiment/flume/camera, a timestack example and the results from a test with $H = 3.3$ cm and $T = 0.75$ s. The 7.0 s test, comprising 168 frames, shows x-coordinate results along the channel for the vertical coordinate (z). Here, $z = 0$ represents the bottom of the channel and the positions of x between 0 and 3500 mm, respectively, indicate the positions closest to the wave maker and to the camera location. The timestack analysis yielded a median value of T of 0.77 s, close to the linear wave theory dispersion relation's median T value of 0.75 s. Wavelength (λ) errors were smallest near the camera end ($x \approx 3500$ mm), gradually increasing towards the far end, reaching up to 30%. At the far end of the channel, the errors take values in the order of 5 to 10% in the section from 1800 to 3200 mm, and up to the first 2000 mm this value gradually increases from 10 to 30%. Regarding the z results, as for λ, it is near the end of the channel closest to the camera where the smallest errors are recorded. In this case, in the last 1250 mm of channel length, the associated error is of the order of 10%. For the rest of the channel length, z-errors became unrealistic due to high errors.

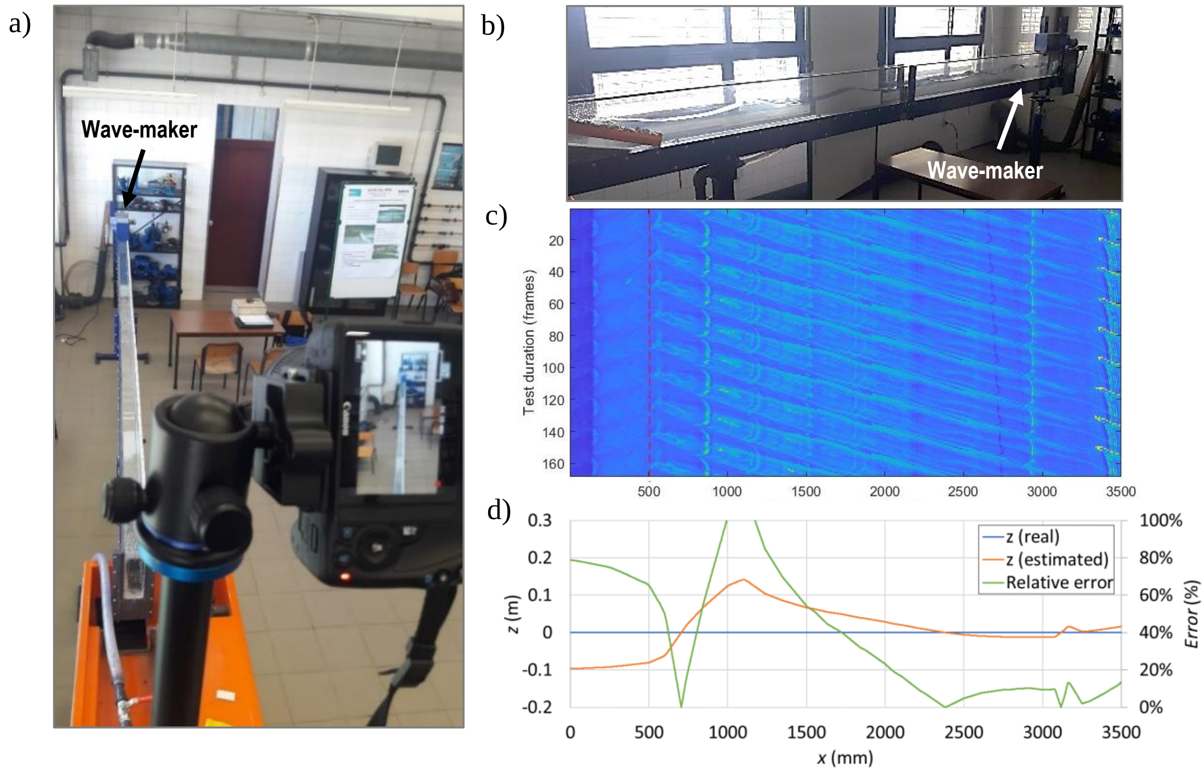

Fig. 1. a) and b) Pictures of the experiment/flume/camera. c) Timestack example for a test with H=3.3 cm and T=0.75 s. d) Real and estimated z values and relative error.

4. Conclusions

Regular wave conditions with varying characteristics, including different wave heights and periods, were generated in a fixed-bottom open channel flow at NOVA School of Science and Technology | FCT NOVA. A video camera recorded the free surface elevation of shoaling waves, enabling the creation of timestacks for inferring the bathymetry of the experiments. Optimal water depth estimates were achieved for the shortest periods and highest wave heights. Due to the channel's limited dimensions, longer periods resulted in a reduced number of observable waves in an image, diminishing result quality. Overall, the bathymetric estimates demonstrated diminished quality in areas farther from the camera, potentially linked to a decrease in image resolution during the image orthorectification process.

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