THE UNIVERSITY OF MELBOURNE

Department of Infrastructure Engineering | Ocean Engineering Group

On Phase-Resolving Simulations of Deep-Water Waves

Wave Absorption using a Static-Boundary Method

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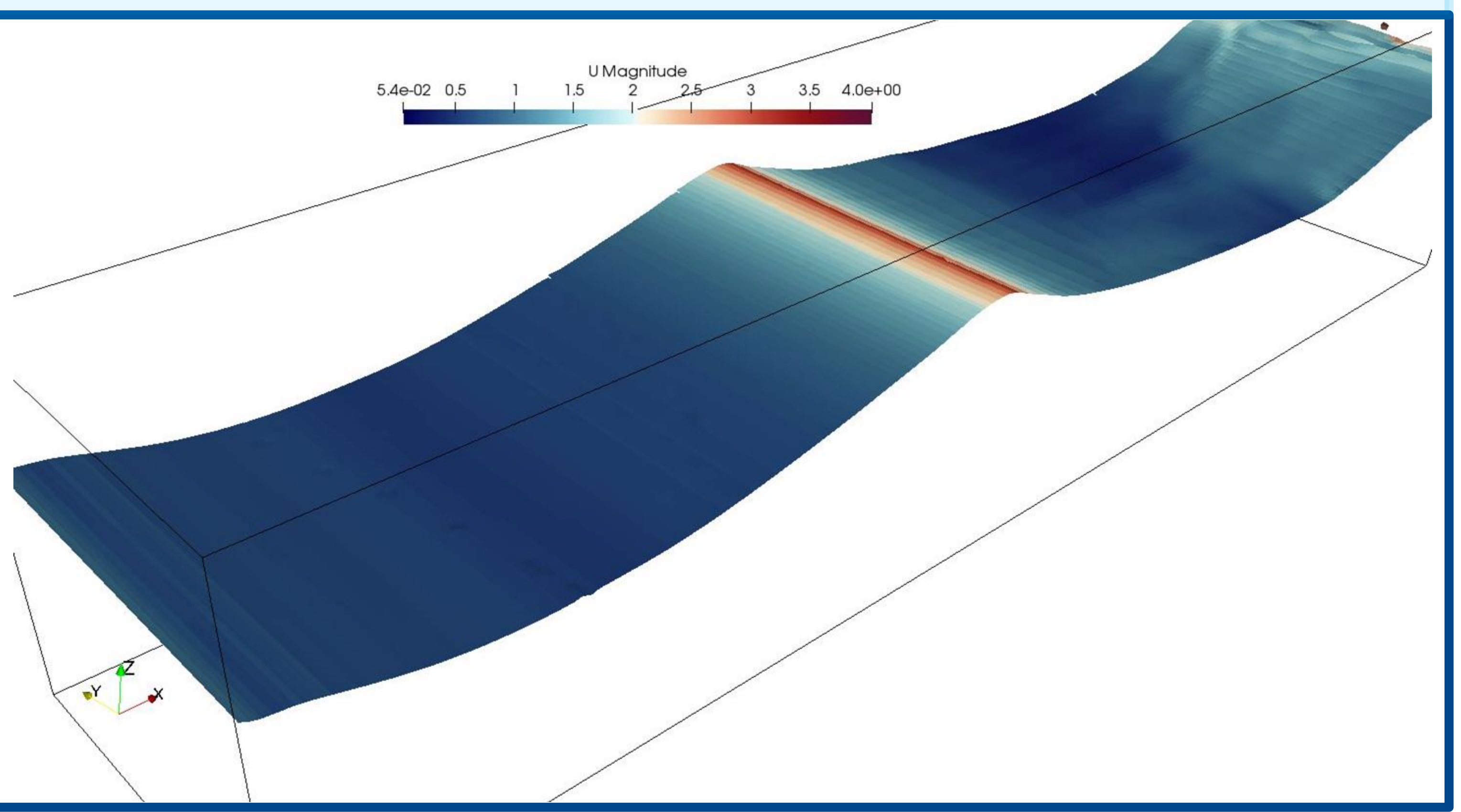
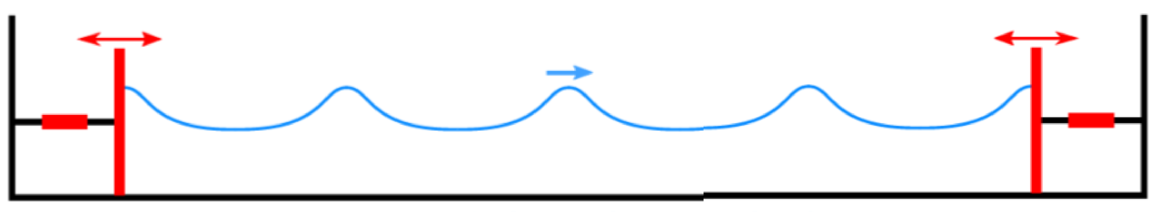
Abstract & Highlights

- The present study extends the applicability of the static-boundary absorption method in phase-resolving CFD simulations to deep-water conditions.
- For this sake, absorption of two-dimensional monochromatic waves in a semi-infinite flume by means of a static wall is investigated theoretically and numerically.
- A phase-resolving numerical model based on the Reynold-averaged Navier-Stokes (RANS) equations is constructed using the open source `C++` toolbox `OpenFOAM`®.
- The study presents the performance of the static-boundary method, in a dimensionless manner, by limiting the depth at which the oscillating currents are introduced; as a function of incident wave conditions.
- Moreover, it is shown that the performance of the static-boundary method can be enhanced where wave reflection was reduced to about half of that of the conventional setup in deep-water conditions.

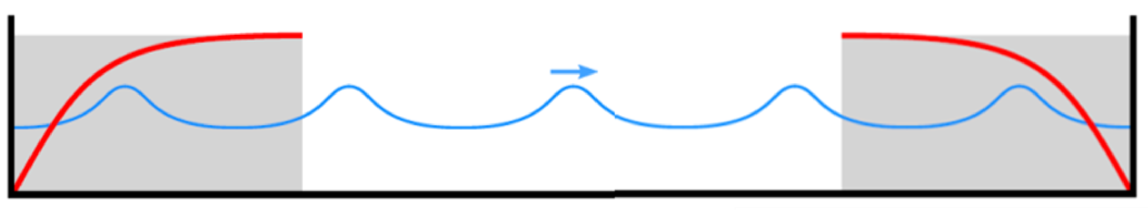


Introduction and Research Objectives

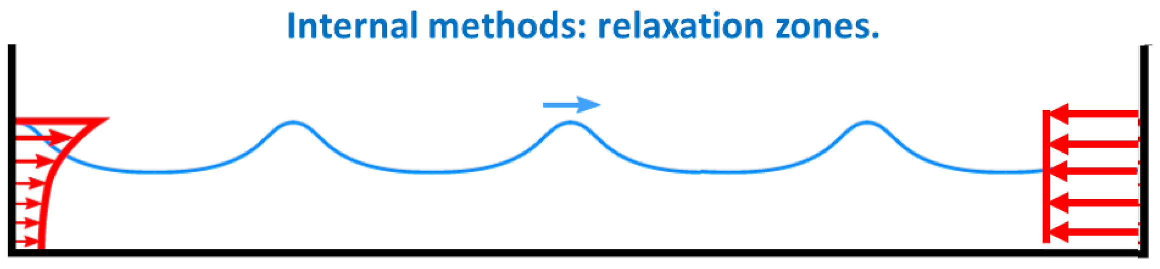
- With the depletion of the relatively easily accessed resources inland and nearshore, industries have been marching further into deeper waters. This, in turn, led to increasing attention of the scientific community toward ocean engineering applications taking place in deep water conditions.
- Phase-resolving numerical simulations of ocean engineering applications are inherently expensive for a multitude of reasons such as interface tracking methods and the wide scale of physical processes that need to be resolved.
- Out of all, the spatial boundedness of a numerical domain compared to a real-life situation; where waves need to be artificially absorbed at the domain bounds to mimic their corresponding real-life ones.
- In other words, wave reflection off domain bounds ought to be prevented by absorbing them to avoid adversely affecting test subjects.
- Consequently, a number of wave absorption techniques have been devised in literature; which can be classified into internal, dynamic-boundary and static-boundary methods.
- The present study aims to extend the range of applicability of the static-boundary absorption method into deep-water conditions.
- Even though this method was originally formulated for shallow-water waves, extending its use to deep-water conditions provides a more practical and computationally cost effective solution compared to other available alternatives.



Dynamic-boundary methods



Internal methods: relaxation zones.



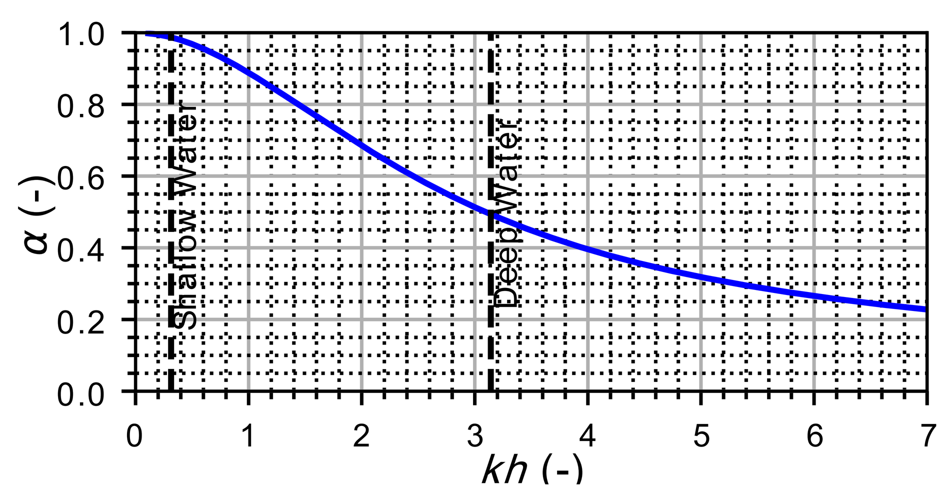
Static-boundary methods

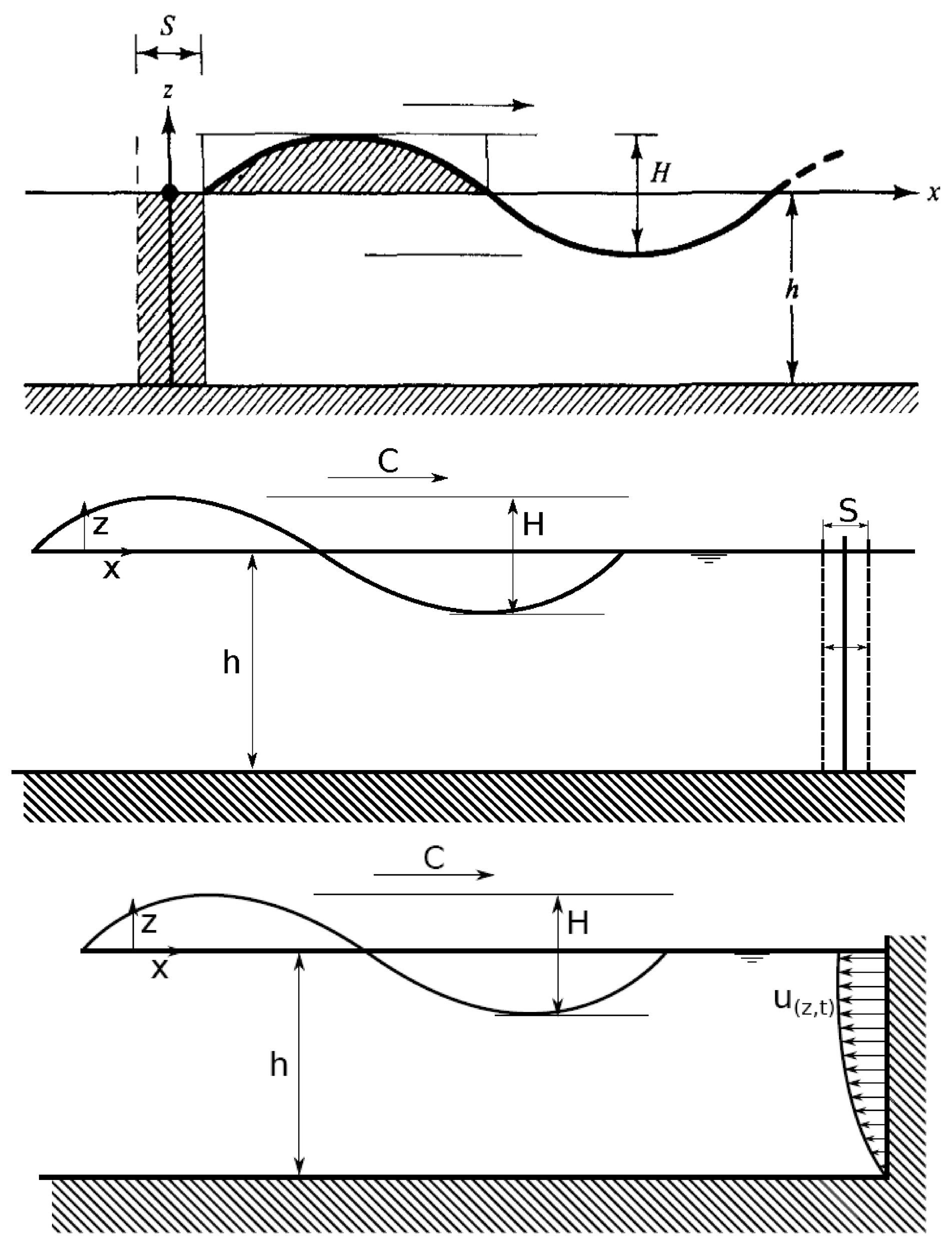
[P. Higuera, 2014]

Theoretical Derivation

- The classical problem of wave absorption by a wall is revisited and investigated from a hydrodynamical perspective.
- This is done by proposing a limiting absorption depth h which corresponds to incident wave conditions, to better match the wave kinematics in deep-water conditions compared to the conventional shallow-water method.
- The proposed solution is easy and straight-forward to be implemented to existing numerical packages without code modifications.

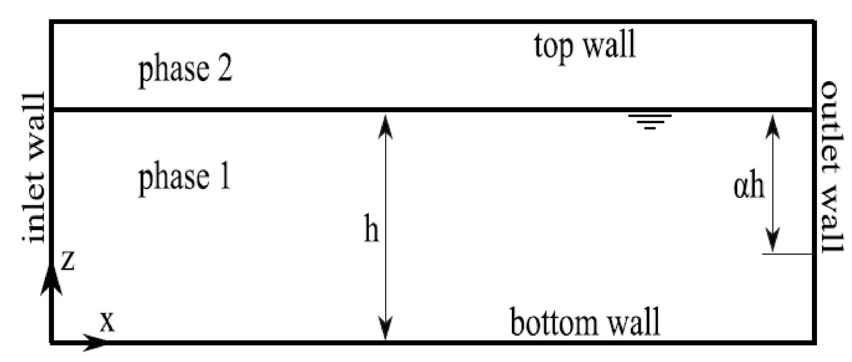
$$\alpha kh = \frac{4sinh(kh)[sinh(kh) - sinh(kh(1-\alpha))]}{sinh(2kh) + 2kh}$$





Results Discussion

- A fully non-linear phase-resolving CFD numerical model is constructed to investigate the effectiveness of the proposed limiter, using different case scenarios of the absorption depth αh.
- Wave height variation along the flume is influenced by the variation of the absorption depth αh.
- Compared to the conventional standard setting (α=1), absorption was greatly enhanced where wave reflection coefficient dropped from ε_r = 28.1% to 12.66%.
- Even though the reflection has been dropped significantly compared to the standard setup, wave reflection is still relatively high and will adversely affect test subjects placed in that flume.
- For this sake, a minimal damping zone is implemented and reflection is further reduced to 4.44%.
- Damping zone is only half-wave-length in size, which is considerably less than other wise a pure absorbing damping zone.



αh	h	$\lambda/2$	$\lambda/4$	$\lambda/18$
$\epsilon_r(\%)$	28.1	22.51	12.66	21.94
$A_k(cm)$	0.543	0.484	0.369	0.54
$\sigma^2(cm^2)$	0.178	0.141	0.083	0.173
$H_s(cm)$	1.69	1.50	1.15	1.66