SPH AND ANALYTICAL MODELING OF AN URBAN FLOATING STRUCTURE FOR COASTAL EXPANSION

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INTRODUCTION

The development of large-scale floating structures is recognized by the American Society of Civil Engineers as a critical step towards resilient coastal cities for climate change adaptation (ASCE, 2019). Yet, a lack of design guidelines acts to limit their development at the community scale. In response, we demonstrate and validate the applicability of a simplified analytical procedure against numerical solutions to elucidate the dynamics of a freely-floating pontoon-building system. This effectively presents a pathway towards the evaluation of structural requirements for the realization of floating cities as a sustainable alternative to traditional land reclamation.

STRUCTURAL DESCRIPTION

The floating structure was based upon the standardized Module9000 platform conceptualized by Wang et al. (2020). An 8.1 m deep pontoon measuring 30 m wide supports buildings 30 m in height (Figure 1). The system exhibits a total displacement of 157000 kg/m and exists in water 18 m deep as representative of the coastal regions of Singapore (Wang et al., 2020).

NUMERICAL AND ANALYTICAL MODELING

The heave (z), sway (y), and roll (θ_x) motions of Module9000 were first computed via smoothed particle hydrodynamics (SPH) under regular waves (generated from an open boundary per Stokes 2nd order wave theory) with periods ranging from 5 to 25 s. To ascertain its veracity, the SPH model was validated against experimental data pertaining to a floating breakwater and a cube drop study observing full 3D rotations (Kraskowski, 2010).

As supplementary to the numerical results, a simplified analytical model was employed to solve the equation of motion when idealizing the floating structure as a mass-spring-damper system:

$$M\ddot{x} + C\dot{x} + Kx = F \tag{1}$$

Here, the harmonic forcing F accounts for Froude-Krylov effects while the added mass was treated as a frequency-independent mass of fluid synchronized with the oscillating body. As such, diffraction analysis is not required and each degree of freedom (DOF) may be decoupled and solved independently.

RESULTS AND CONCLUSIONS

Comparisons were made between SPH and analytical solutions in terms of the response amplitude operator (RAO) for heave, sway, and roll under regular waves. Since heave and roll DOFs are stiffness dominated, damping ratios (ξ) ranging from 0 to 0.3 were examined as part of the analytical study. It was revealed that the simplified method was capable in describing the motions of Module9000 across all DOFs and wave periods considered. In addition, a damping ratio between 0.1 and 0.2 appears optimal when attempting to provide a conservative estimate of the heave and roll RAOs for preliminary design applications. As an example, the RAO for roll is shown via Figure 2.

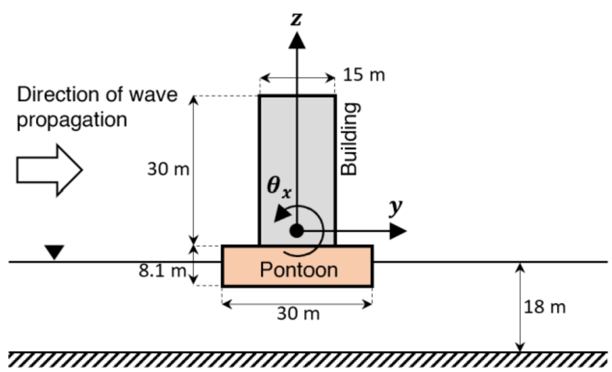

Figure 1 - Schematic of the Module9000 floating structure

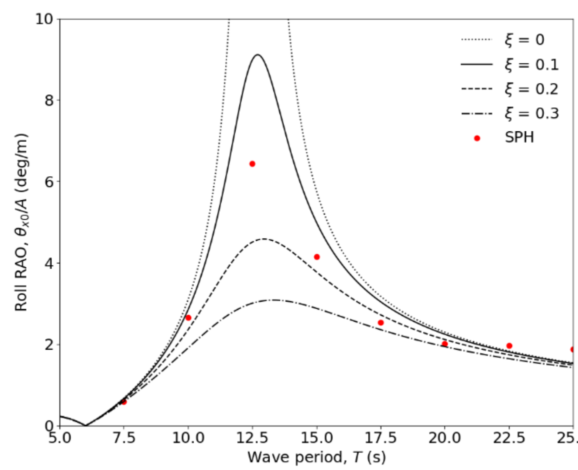

Figure 2 - RAO of Module9000 in roll

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