IMPLICATIONS OF SECOND-ORDER WAVE GENERATION FOR USE IN WAVE-STRUCUTRE RESPONSE EXPERIMENTS

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SUMMARY

Results of novel second-order wave generation, used to remove contaminating error waves in physical experiments will be presented. The implications of error waves on coastal responses is quantified through comparison of first-order generated (FOG) and second-order generated (SOG) wave group experiments.

INTRODUCTION

Globally, coastal populations are displaying rapid growth, whilst climate change pressures are increasing the risk of flooding and wave damage (Kontogianni et al. 2019). Coastal communities and critical coastal assets are therefore increasingly reliant on engineered protection from wave-induced flooding. Dynamic wave force and wave run-up are among key design parameters of such protection. Dynamic wave force; the horizontal force exerted on a structure during a wave-structure interaction, excluding the hydro-static force (Goda, 2010), and run-up; the maximum elevation waves reach above the still-water level (Sorensen et al. 2005). Excessive force can lead to structural failure (e.g., Dawson et al. 2016) and excessive run-up can lead to overtopping and flooding (Goda, 2010).

Present understanding of coastal wave-structure interactions and responses was gained through large databases of experimental data as well as numerical, and field measurements. Such databases are widely used to inform engineering best practice, such as the EurOtop manual Pullen et al. (2007), later revised in 2018, for overtopping on coastal structures. It is well known that experimental data of wave-structure interaction are contaminated by second-order error waves at sub- and super-harmonic frequencies when first-order wave generation is used. The error waves arise from disparity between linear wave-maker signals and non-linear boundary conditions at the wave generator. Orszaghova et al. (2014) showed numerically that error waves significantly increase run-up (18-57%) and overtopping volume (25-83%) on sloped structures. Often in excess of safety margins in structure design.

Herein, we conduct a novel investigation by experiment of the implications of second-order wave generation for dynamic wave force and run-up on a vertical wall, in shallower depths than previously published (kd = 0.6 - 1.1). Short-duration experiments are conducted, using identical focused wave groups generated according to first- and second-order theory. Results are subsequently compared. We isolate linear, sub-, and super-harmonic contributions using different combinations of inverted wave group time series and frequency filtering. We derive theoretical predictions for second-order wave groups interacting with a vertical wall and use this to calculate depth-integrated force and run-up on the wall. Figure 1, displays preliminary results, the measured SOG response (blue dots) and theory (black dashed line) show close agreement. Whereas the FOG responses (red dots) have poor agreement with theory. Harmonic comparisons reveal that sub-harmonic error waves are increasingly important in shallow depth, typical of coastal engineering, and lead to increased wave run-up by up to 67% and dynamic force by up to 75% at kd = 0.6.

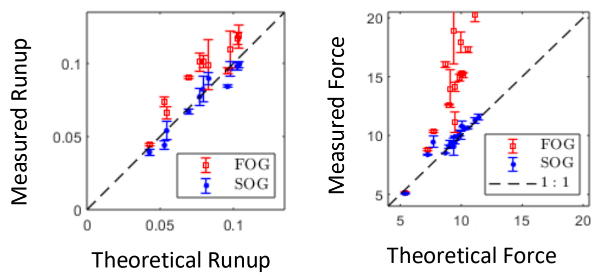

Figure 1: Preliminary results of FOG and SOG runup (left) and force (right) compared against theory (black dashed).

CONCLUSION

The findings of the present work are significantly important to consider before experimental results, generated using first-order wave generation theory, are used to inform structure designs. Not accounting for second-order error waves in such scenario could lead to greater expected wave-induced run-up and force and subsequently, overly conservative design parameters.

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