Calculations of Wave Run-up on Cylinder in Multi-Directional Focused Waves

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ABSTRACT
The present paper is concerned with the problem of estimating wave run-up on a vertical circular cylinder in an extreme wave environment. The waves are generated in a 3D wave basin using a focused wave method with different frequency and directional components. A practical method based on the velocity stagnation head theory ($R_u = \eta_{max} + \mu u^2/2$) is calibrated to calculate the wave run-up. The maximum wave kinematics at wave crest $u$ is calculated using second-order theory. Wave run-up on the weather side of the cylinder is calculated and compared with measurements of wave run-up in experiments with multi-directional focused wave groups. The relations between defined parameter $m$ and the wave parameters, such as model scale, directional spreading index and wave steepness, are discussed. The results reveal that these wave parameters have no significant influence on the value of coefficient $m$. An average value $m = 3.25$ is proposed for all experimental cases.

KEY WORDS: Wave run-up; multi-directional focused wave; velocity stagnation head theory.

INTRODUCTION
In recent decades, many structures have been built on the ocean for the purpose of developing ocean energy. Most of these structures are comprised of a deck supported by large columns penetrating the water surface (Fig. 1). The design of such a structure must consider the 'air gap', which is the distance from the platform deck to the mean water level. A small air gap design can pose a security problem for the platform, while a larger air gap can increase the fabrication costs as well as affect the platform stability. One design concern, especially in extreme wave conditions, is how to accurately predict the wave run-up on these structures.

Many publications have addressed calculations of wave run-up on oceanic structures. Linear diffraction theory enables the calculation of a wave field around a body of arbitrary shape. This theory is valid for sufficiently small wave heights, where linear wave theory is applicable.

Haney and Herbich (1982) predicted that the run-up ratio at the upwave side of a cylinder is given approximately by

$$R_u = \eta_{max}[1+(4k\alpha)^{1/2}]$$

(1)

Where $R_u$ is the elevation of the water on the cylinder above SWL, and $\eta_{max}$ is the crest elevation. Kriebel (1993) later found that this theory underestimated the run-up. Experiments have shown that there were significant nonlinear contributions in the case of steep waves, leading to a considerable amplification of the water surface elevation. Kriebel (1990, 1992) developed a second-order diffraction theory and used it to investigate the regular wave run-up on a cylinder. His results showed that the second order theory also underestimated the wave run-up, especially for steep wave. Morris-Thomas and Thiagarajan (2004) investigated wave run-up on a fixed vertical cylinder using an experimental method, and their results confirmed that the complete wave run-up was not well accounted for by second order diffraction theory.

Fig. 1 Typical oceanic platform.

Hallermeier (1976) proposed a velocity stagnation head theory to estimate wave run-up on ocean structures. The theory considers the stagnation head at the wave crest as it strikes the vertical cylinder,