Applied Ocean Research 71 (2018) 105–118

Contents lists available at ScienceDirect

Applied Ocean Research

journal homepage: www.elsevier.com/locate/apor

Wave run-up on a fixed surface-piercing square column using multi-layer barrier

Zhichao Fang[a,b], Longfei Xiao[a,b,*], Yinghao Guo[a,b], Yufeng Kou[a,b], Jun Li[a,b]

[a] State Key Laboratory of Ocean Engineering, Shanghai Jiao Tong University, 800 Dongchuan Rd., Shanghai 200240, China
[b] Collaborative Innovation Center for Advanced Ship and Deep-Sea Exploration, Shanghai 200240, China

ARTICLE INFO

Article history:
Received 1 September 2017
Received in revised form
16 December 2017
Accepted 22 December 2017

Keywords:
Wave run-up
Surface-piercing square column
Multi-layer uprush barrier
Porous plate
Slamming

ABSTRACT

Steep or breaking waves may produce critical run-ups on a surface-piercing column, as represented by an unexpectedly high uprush, which has the potential of generating damaging localised wave-in-deck loads. Hence, to improve the air gap performance of offshore column-stabilised platforms, this paper proposes the mounting of an innovative multi-layer barrier on the column surface at a certain distance below the lower deck. Experiments were performed using a truncated square column to examine the performances of different versions of the barrier, namely, solid-plate, porous-plate, and intermittent-plate types, under four different focused waves. All the barrier types were found to obstruct and deflect uprush flow under storm conditions. However, the solid-plate type tended to experience considerable wave forces, with its impermeability also rendering the higher layers ineffective. The intermittent-plate type dissipated the uprush flow and decreased the wave impact, although it exhibited relatively strong flow disengaging, which decreased the efficiency under large wave run-ups. Conversely, the porous-plate type exhibited adequate performance, with a larger plate porosity and moderately high mounting elevation tending to improve the uprush obstruction performance and further decrease the wave slamming loads. A barrier with an appropriately designed plate porosity, number of layers, and mount elevation is expected to perform efficiently under severe sea states, providing protection for the lower deck against extreme wave run-ups.

© 2017 Elsevier Ltd. All rights reserved.

1. Introduction

Wave run-up has been of increasing concern in offshore engineering practice, especially with the occurrence of extreme weather conditions in recent years. The highly nonlinear phenomenon is of significance in the air gap design because of its potential to cause unexpected damage to offshore structures under extreme conditions, such as the damage of the Brent Bravo gravity-based structure (GBS) that occurred in January 1995 and the fatal accident involving the drilling rig COSL Innovator on the 30th of December 2015. Latheef and Swan [1] showed that waves under severe sea states were steeper and more likely to break. This implies the wave impact due to a wave run-up is greater than is commonly predicted.

Wave run-up on a surface-piercing column usually involves significant local free-surface elevation in the vicinity of the column when it is impacted by the incident wave. In [2], the solution for circular columns based on the second-order diffraction theory found that the run-up height may reach approximately 1.3 times the crest height of the incident wave. The run-up height significantly increases with increasing steepness of the incident wave. Experimental investigation [3] has also shown that the maximum run-up height in front of a truncated circular column is approximately 1.6 times the incident wave amplitude for a steep monochromatic wave ($H/\lambda = 9.2\%$, where H and λ are respectively the wave height and length), with the value reaching 2.5 for a square column with rounded corners. Similar results were reported in [4], which specified a maximum run-up height of approximately 2.5 times the incident wave crest height for both full-length and truncated circular columns. Numerical investigation conducted by Bai and Taylor [5] using a fully nonlinear wave tank indicated that the wave run-up height under a steep focused wave group could reach 2.6 times the maximum incident wave crest height. In the case of multi-column structures, the inter-column interference between incident and diffracted waves (and radiated waves in the case of floating plat-

---

* Corresponding author at: State Key Laboratory of Ocean Engineering, Shanghai Jiao Tong University, 800 Dongchuan Rd., Shanghai 200240, China.

E-mail addresses: zhichaofang@sjtu.org (Z. Fang), xiaolf@sjtu.edu.cn (L. Xiao), gyouth@sjtu.edu.cn (Y. Guo), kouyufeng@sjtu.edu.cn (Y. Kou), lijunocean@sjtu.edu.cn (J. Li).

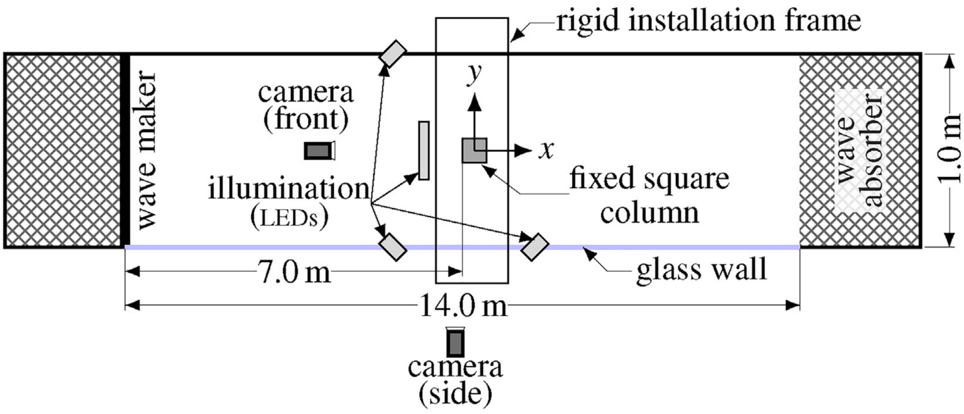
https://doi.org/10.1016/j.apor.2017.12.010
0141-1187/© 2017 Elsevier Ltd. All rights reserved.

forms) may further increase the run-up height to nearly three times the incident wave crest height [6]. The underlying caissons of a GBS and the horizontal pontoons of semisubmersible and tension-leg platform (TLP) systems also contribute to the run-up height [7,8]. In the case of a very steep incident wave, the uprush flow can form free jets with significantly high vertical velocities. Roos et al. [9,10] reported that the maximum vertical velocity of a wave run-up on a GBS could reach about 32 m/s, resulting in large wave-in-deck loads. Wave run-up also occurs on columns with relatively small diameters, around which the flow may fall outside the diffraction regime. Vos et al. [11] and Andersen et al. [12] reported the unexpected occurrence of wave run-up on the foundation of one of the wind turbines of the Horns Rev wind mill farm even though the significant wave height was only approximately 2.5 m. This resulted in the damage of a platform and its boat landing facilities.

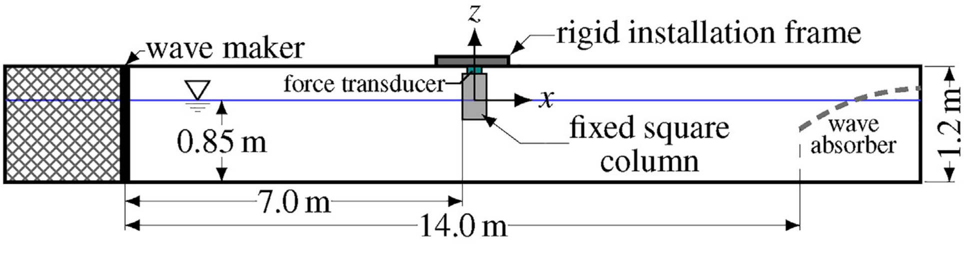
More recent investigations have revealed some detailed nonlinear features of a run-up flow. Roos et al. [10] illustrated the spatial profiles of the run-up flow on the drill shaft of a GBS under a severe storm. The thickness of the run-up flow was shown to decrease rapidly as it rushes up a column, being only approximately 10 mm (less than 10% of the column diameter) near the top of the column. Similar trends have been observed from the wave elevation plots for a steep focused wave run-up event [5]. Experimental observations [13] indicated that the typical thickness of local run-up jets for a circular column of diameter 16 m was approximately 1 m (full scale), with the velocity being approximately 20 m/s. In [14], the uprush flow of a wave run-up was classified into three levels, namely, Level A: a thick layer of green water run-up; Level B: a thin layer of comprising a mixture of water and air; and Level C: the maximum spray. Experimental observation showed that the height of Level C was more than twice that of Level A for a steep focused wave, and that the velocities of the thinner upper levels were relatively high.

To avoid negative air gap resulting from a wave run-up flow, increasing the deck elevation has been a common measure in the design of column-stabilised platforms. However, hydrodynamic and economic considerations make it worthwhile to investigate alternative measures for improving the air gap performance. In view of the thin but relatively high-velocity uprush flow under severe sea states, this paper proposes the use of an innovative multi-layer barrier to obstruct the run-up flow. The barrier was designed for mounting on the column surface at a certain distance below the lower deck, but sufficiently high above the still water level. Obstruction of the uprush flow only comes into play for critical wave run-ups, and the barrier thus does not affect the hydrodynamic performance of the platform under operational sea states. In addition, the thickness of the barrier is small compared with the dimensions of the column in order not to interfere the original platform configuration.

The focus of the present study was the examination of the efficiency of the proposed multi-layer barrier during extreme wave run-up events. For this purpose, wave run-up experiments were performed using truncated square-section columns with and without the proposed barrier. A square-section column is expected to experience more significant wave run-up and is also more convenient for calibration of the camera and installation of the barrier. Different versions of the barrier were tested, namely, solid-plate, porous-plate, and intermittent-plate types. Focused waves were implemented in the experiments to realistically model the impact of extreme waves on a vertical column. Focused waves also have the advantage of enabling the simulation of the interaction of structures with ocean waves of a broad band spectrum within a relatively short time, and are suitable for preforming experiments in a wave flume [15]. More importantly, the superposition of long and short wave components at the focus position enables the achievement of a steeper or breaking wave [16,17], and hence a more critical wave run-up event. In addition, according to the discussion on the nonlinear interaction between a *Type-2* wave and the next incident wave in [18], the diffracted wave of the former wave crest is expected



(a) top view



(b) side view

Fig. 1. Schematic of the wave flume and physical model setup.

Download English Version:

https://daneshyari.com/en/article/8059335

Download Persian Version:

https://daneshyari.com/article/8059335

Daneshyari.com