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The hydrodynamic characteristics of a single suspended row of half pipes under regular waves

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ABSTRACT

In this paper, the hydrodynamic performance of a new type breakwater is studied using physical models. The breakwater consists of one row of half pipes suspended on supporting piles. The transmission, the reflection, and the wave energy dissipation coefficients are presented for different wave and structure parameters. The results indicate that the performance of the proposed breakwater becomes efficient when: (1) the half pipes are horizontal; (2) the diameter of the half pipes is increased; (3) the breakwater inclination angle is 45°; (4) the breakwater draft is greater than the half of the water depth; and (5) the wavelength is more than two times the water depth. In addition, the proposed breakwater type gives high performance when compared with the other similar breakwater systems, e.g. suspended vertical or horizontal pipes and slots, by about 5%–40%.

1. Introduction

Coastal areas are considered of high value regarding their strategic location for residential, recreational, commercial, and industrial activities. Hence, it is desirable to preserve and maintain the coast against the destructive forces of nature such as waves and currents. Different types of breakwaters are in use throughout the world for this purpose. Fixed type breakwaters, like rubble mound, are suitable but very expensive for larger water depths, and require competent soil layers, which may not exist. Therefore, it is necessary to consider cost-effective structures for these depths to attenuate the incident wave heights and dissipate the incident wave energy (Koraim, 2005).

For solving the above-mentioned problems, thin suspended structures are suggested. In general the main advantages of the thin suspended types when compared with the other conventional bottom founded breakwaters are: (1) easy on-land fabrication; (2) quick installation using floating barges; (3) relatively inexpensive when compared with the other commonly used types; (4) less maintenance cost; (5) used in areas where poor soil conditions prevail; (6) conventional solution in deeper waters; (7) occupy a relatively small zone inducing little effects in the benthic environment; and (8) allowing for the continuous refreshing of the shore area water masses which in turn minimizes the pollution aspects, and thus being environmental friendly.

A shore protection type that consists of one row of half pipes suspending on supporting piles driven in the near-shore zone is suggested. This type of shore protection system helps in dissipating energy of the incident sea waves by its high friction and protecting shorelines from erosion by wave attack. In addition, it is relatively inexpensive when compared with the other thin suspended types.

The study of wave transmission, reflection, and energy dissipation due to this structure is the key information necessary to understand the hydrodynamic performance of this structure as a special type of breakwater. The information on the characteristics of wave transmission is essential in selecting the appropriate configuration (pipe diameter, draft, etc.) for a prevailing wave climate once the permissible range of transmission is decided for the protected areas. Knowledge of wave reflection in the vicinity of this structure is necessary to select its crest level.

2. Previous work

There is little published material on this type of breakwater. Similar models such as semi-immersed smooth solid walls, slots barriers, and pipe breakwaters were previously studied. There are many vertical thin structures similar to the proposed breakwater built around the world such as (1) a steel pipe breakwater at port of Osaka, Japan; (2) a concrete pipe breakwater at Pass Christian,

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Nomenclature

b	breakwater width
d	pipes diameter
D	breakwater draft
g	acceleration of gravity
h	water depth
H_i	incident wave height
H_r	reflected wave height
H_t	transmitted wave height
k	incident wave number
k_L	energy dissipation coefficient
k_r	reflection coefficient
k_t	transmission coefficient
L	wavelength
$L_{max.}$	maximum wavelength
T	wave period
θ	breakwater inclination angle

USA; (3) a steel pipe breakwater at Pelangi Beach Resort, Langkawi, Malaysia, (4) a wooden pile groin at the southern coast of the Baltic Sea, Germany; and (5) a curtain wall-pile breakwater at the port of Yeoho, Korea.

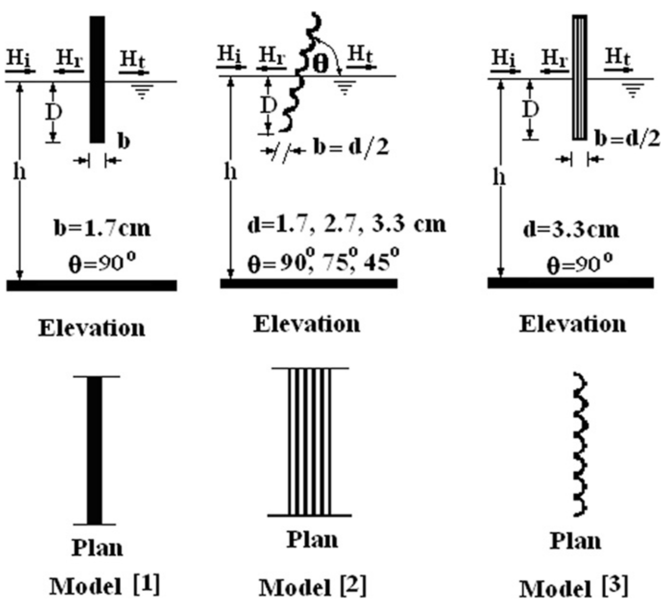

Fig. 1. Details of the tested breakwater models.

The efficiency of the semi-immersed walls was experimentally and theoretically studied by many researchers. Ursell (1947), Weigel (1960), Reddy and Neelamani (1992), Heikal (1997), and Koraim (2005) carried out experimental studies to determine the efficiency of this type of breakwaters. Liu and Abbaspour (1982) developed a theoretical solution using Boundary Integral Method for analyzing the interaction between the water wave and the breakwater. Losada et al. (1992), Abul-Azm (1993), Heikal (1997), Sahoo et al. (2000), and Heikal (2007) developed theoretical models using the Eigenfunction Expansion Method to determine the efficiency of such breakwater type.

In order to examine the wave scattering by vertical slotted breakwaters, physical and theoretical models were developed by many authors such as, Kriebel (1992), Isaacson et al. (1998), Abdel-Mawla and Balah (2001), Huang (2007), and Koraim (2007). Nagai (1966), Mani and Jayakumar (1995), Mani (1998), Galal (2002) and Rao et al. (2003) studied the performance of the pipe breakwater using different physical and theoretical models.

In this study, the efficiency of a breakwater that consists of one row of half pipes suspended on supporting piles is investigated using physical models. The breakwater efficiency is valuated through the calculation of transmission, reflection, and wave energy dissipation coefficients. The effect of different wave and structural

Table 1
Experimental setup parameters for the half pipe breakwater.

Parameter	Units	Ranges	Notes
Water depth (h)	m	0.20	At the breakwater sit
Wave periods (T)	s	0.65–1.33	
Wave length (L)	m	0.63–1.75	At the breakwater sit
Relative wave length (h/L)	–	0.13–0.30	At the breakwater sit
Dimensionless wave steepness (H_i/gT^2)	–	0.003–0.013	At the breakwater sit
Pipe diameter (d)	m	0.017, 0.027 and 0.033	
Breakwater draft ratio (D/h)	–	0.0–0.85	
Breakwater inclination angle (θ°)	degree	90°, 75°, and 45°	

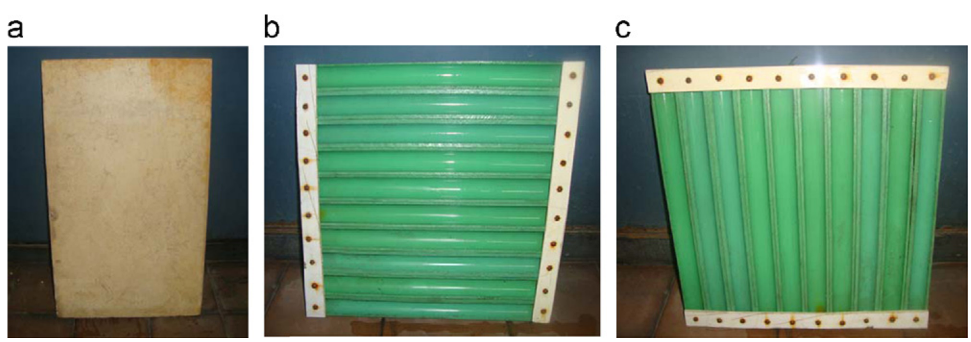

Fig. 2. General view of the tested breakwater models. (a) Smooth model [Model 1], (b) Horizontal half pipes [Model 2] and (c) Vertical half pipes [Model 3].