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Hydrodynamic Performance Characteristics of Emerged Perforated Quarter Circle Breakwater

Binumol.S[1], Subba Rao [2], Arkal Vittal Hegde[3]

PhD. Student, Department of Applied Mechanics & Hydraulics, NITK Surathkal, Mangalore, India[1]

Professor, Department of Applied Mechanics & Hydraulics, NITK Surathkal, Mangalore, India[2, 3]

ABSTRACT: Breakwaters are one of the most important harbour structures constructed to withstand and dissipate the dynamic energy due to the action of the waves. Due to fast growing need of the universe and advances in technology different types of breakwaters are being developed. Quarter circle breakwater is a new type of breakwater emerged from semi-circular breakwater and the first model was developed in Peoples Republic of China (2006).The present study investigates the wave reflection, wave runup and rundown on an emerged seaside perforated quarter circle breakwater of radius 55 cm and with ratio of spacing to diameter of perforations (S/D) equal to 4 for different water depths.

KEYWORDS: Quarter Circle Breakwater, Perforations, Wave reflection, Wave runup and Wave rundown.

I. INTRODUCTION

Quarter circle breakwaters (QBW) are new type breakwaters first proposed by Xie et al. (2006) on the basis of SBW concept. The superstructure of QBW consists of a quarter circular surfaces facing incoming wave, a horizontal bottom and a rear vertical wall mounted on rubble mound foundation (Refer Fig. 1).Quarter circle breakwater with perforations possess merits of caisson as well as perforated breakwaters such as low weight, requires less materials, suited for poor soil conditions, easily transported, handled and placed at the site, aesthetically pleasing, cost effective, eco- friendly and stable. The most important benefit of QBW is the reduction in the volume of concrete as well as rubble mound foundation, because of the smaller bottom width (HanbinGu et al. 2008).

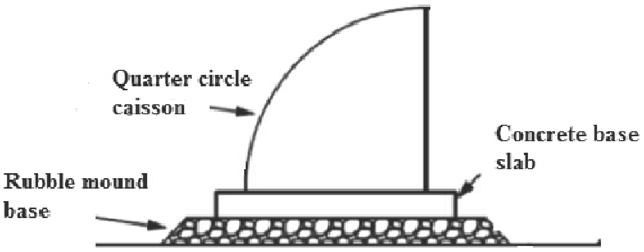

Fig. 1 Typical QBW section

Jarlan (1961) introduced the concept of perforated breakwater with a front perforated wall, a wave energy dissipating chamber and a solid back wall. Significant damping of incoming wave can be achieved by the generation eddies a turbulence near the perforations in the front wall (Jarlan, 1961). With the evolution of different forms of perforated breakwater, researchers conducted a lot of experimental studies introducing new concepts in the design of perforated breakwater.Xieet al. (2006) evaluated the hydraulic characteristics of quarter circle breakwater (QBW) by a numerical flume and concluded the main reason for the difference of wave forces on the quarter circle and the semicircular breakwater (SBW).Jiang et al. (2008) conducted a 2-D (vertical) wave numerical model and physical model studies to research the performances of QBW by comparing the hydraulic behaviours of SBW and QBW under same hydraulic conditions.Qie et al. (2013) conducted a series of physical model tests acted by irregular waves to investigate the wave force distribution on the seaward side of QBW. Studies conducted so far on QBW were mainly concentrated on wave reflection and wave forces on impermeable QBW. Therefore it is necessary to carry out detailed studies to investigate the various hydrodynamic performance characteristics of emerged perforated QBW.

II. EXPERIMENTAL INVESTIGATIONS

The physical model study for regular waves was conducted in a two dimensional wave flume at National Institute of Technology, Karnataka, Surathkal, Mangalore which is 50 m long, 0.71 m wide and 1.1 m deep (Refer Fig.1).Waves of height ranging from 0.03 m to 0.24 m heights and periods from 1.0 sec to 3.0 sec can be generated with this facility. To simulate the field conditions of wave height, period and diameter of perforation by application of Froude's law (Hughes, 1993) a geometrically similar model scale of 1:30 was selected for the present experimental investigations.

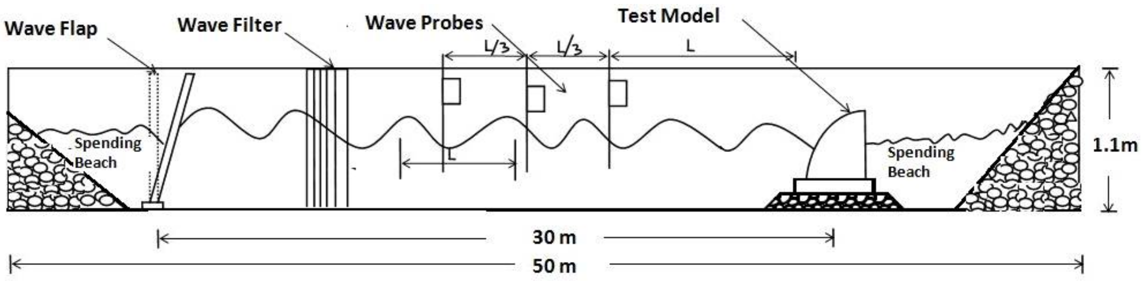

Fig.2 Longitudinal Section of Wave Flume (Not to Scale)

For the experimental studies QBW models of radius (R = 0.550 m) and S/D ratio equal to 4 is selected for the study. The model dimensions are selected to satisfy the condition that the model will be emerged at all water depths (d = 0.35 m, 0.40 m and 0.45 m) and remains non-overtopped under all wave conditions.

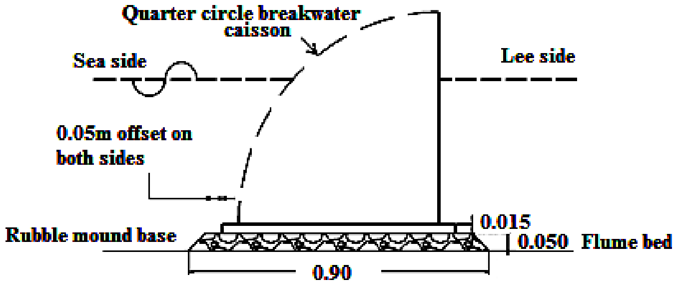

Fig. 3 Cross section of Sea side perforated QBW

The proposed model of QBW consists of two parts, the bottom concrete slab and the top quarter circle shaped caisson (Refer Fig. 2 and Fig. 3). Galvanized Iron sheet of 0.002 m thickness was used to fabricate the quarter circle caissons of radius 0.55 m, 0.575 m and 0.60 m. The sheet is fixed to the slab with the help of stiffeners made up of flat plates of cross section 0.025 m x 0.005 m. The model is then placed over the rubble mound foundation of thickness 0.05 m and stones weighing from 50 gm to 100 gm.

III. EXPERIMENTAL RESULTS

The data collected from the studies was expressed as non-dimensional parameters. The variation of reflection coefficient $K_{r,}$ relative wave runup R_u/H_i and relative wave rundown $R_{d/}H_i$ for varying incident wave steepness (H_i/gT^2), relative water depth (d/ h_s) was analyzed separately by plotting non-dimensional graphs.

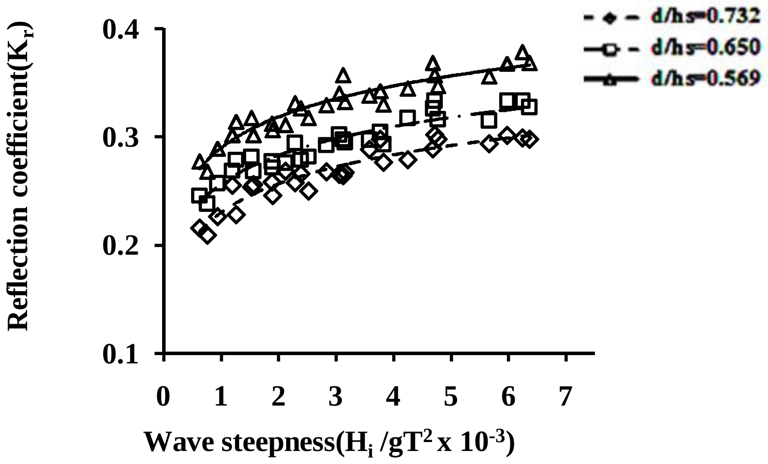

Fig. 4 Influence of H_i/gT^2 on K_r for S/D=4 and at different water depths

Figure 4 shows the variation of K_r with H_i/gT^2 for different water depths with radius of breakwater constant (R = 55 cm) and S/D ratio equal to 4. The values for K_r increases with increase in H_i/gT^2 for all values of d/h_s and S/D=4. Considering all values d/h_s and for breakwater radius of 55cm, the reflection coefficient, K_r varies from 0.2090 to 0.3780 for $6.24x10^{-4}<H_i/gT^2>6.4x10^{-3}$. The highest value for K_r observed was 0.3780 at a wave height of 0.12 m and a wave period of 1.4 s (H_i/gT^2 = 6.241 $x10^{-3}$) and at water depth equal to 35cm (d/h_s equal to 0.569). The lowest K_r observed was 0.2090 at a wave height of 0.03 m and a wave period of 2s (H_i/gT^2 = 7.645 $x10^{-4}$) and at water depth equal to 45cm (d/h_s equal to 0.732).

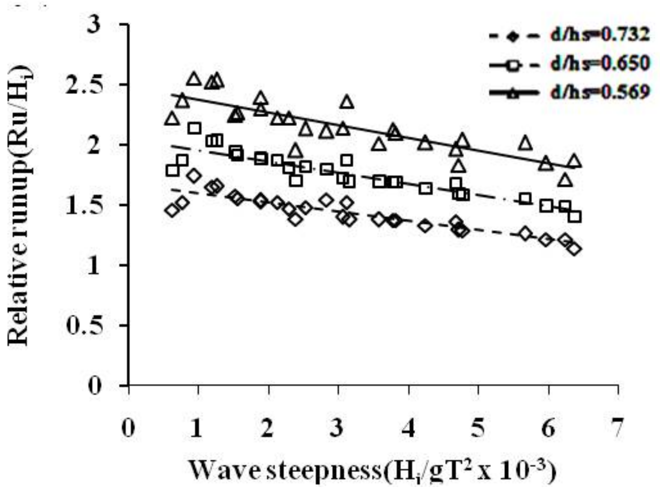

Fig. 5Influence of H_i/gT^2 on R_u/H_i for S/D=4 and at different water depths

Figures 5shows the variation of R_u/H_i with H_i/gT^2 for different water depths with radius of breakwater constant (R = 55 cm) and S/D ratio equal to 4.The values of the relative runup, R_u/H_i varies from 1.140 to 2.552 for $6.24x10^{-4} < H_i/gT^2 < 6.4x10^{-3}$. The maximum R_u/H_i observed was 2.552 at a wave height of 0.03 m and a wave period of 1.8 s (H_i/gT^2 = 9.439 $x10^{-4}$) and at water depth equal to 35cm (d/h_s equal to 0.569). The minimum R_u/H_i observed was 1.140 at a wave height of 0.09 m and a wave period of 1.2s (H_i/gT^2 = 6.3710 $x10^{-3}$) and at water depth equal to 45cm (d/h_s equal to 0.732).

For water depth equal to 45cm and QBW radius equal to 55cm, the maximum value for R_u/H_i was 1.739 at a wave height of 0.03 m and a wave period of 1.8 s (H_i/gT^2 = 9.439 $x10^{-4}$). At the same water depth, the minimum value of R_u/H_i obtained was 1.140 for H_i/gT^2 = 6.371 $x10^{-3}$.

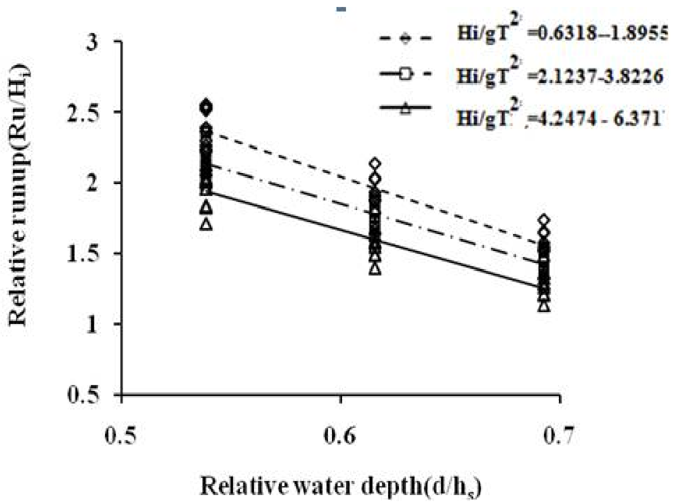

Fig. 6 Variation of R_u/H_i with d/h_s, S/D=4

For water depth equal to 40cm (d/h_s equal to 0.650), the maximum value for R_u/H_i observed was 2.139 for H_i/gT^2 = 9.439 x10^{-4}. The minimum value of R_u/H_i obtained was 1.402 for H_i/gT^2 = 6.371 x10^{-3}.At a water depth equal to 35cm (d/h_s equal to 0.569), the maximum and the minimum value for R_u/H_i observed was 2.552 and 1.715 for H_i/gT^2 = 9.439 x10^{-4} and 6.241 x10^{-3} respectively. As water depth increases from 0.35 m to 0.40 there is a reduction in $R_u/H_i$by 16.18% to 18.25% .When water depth increases from 0.35 m to 0.45m there is a reduction in $R_u/H_i$by 31.85 to 33.53%.

For S/D equal to 4, the maximum value of R_d/H_i observed was 1.2643 at a wave height of 0.03 m and a wave period of 1.6 s (H_i/gT^2 = 1.1946 x10^{-3}) at water depth equal to 45cm (d/h_s = 0.732).The maximum value of R_d/H_i observed was 1.0350 at a wave height of 0.03 m and a wave period of 2.2 s (H_i/gT^2 = 6.318 x10^{-4}) and at water depth equal to 40cm (d/h_s = 0.650). The maximum value of R_d/H_i observed was 0.8549 at a wave height of 0.03 m and a wave period of 1.8 s (H_i/gT^2 = 9.439 x10^{-4}) and at water depth equal to 35cm (d/h_s = 0.569).

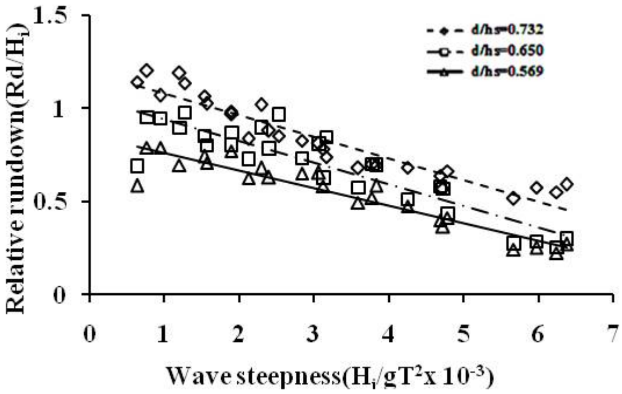

Fig. 7 Influence of H_i/gT^2 on R_d/H_i for S/D=4 at different water depths

IV. CONCLUSIONS

The reflection coefficient, K_r increases with increase in H_i/gT^2 for all values of d/h_s. The minimum K_r observed was 0.5054 for QBW of radius equal to 55cm at H_i/gT^2 = 9.439 x10^{-4} and at water depth equal to 45cm (d/h_s = 0.732). The non-dimensional reflection coefficient K_r decreases with increase in water depth (d/h_s). With respect to a water depth of 35cm, the maximum percentage reduction in K_r was observed at 45cm water depth and was found to be varying from 17.35% -19.27%, for QBW of radius equal to 55cm. When the wave steepness increases, the waves will be of short wave period which will resulting the interaction with QBW for short period causing lesser dissipation of wave energy and hence higher values for K_r. Also at higher water depths, the curved face of the QBW is more subjected to wave action causing more dissipation of wave energy and hence lower K_r values.

The relative wave run up, R_u/H_i and the relative wave run down R_d/H_i decreases with increase in H_i/gT^2 for all values of d/h_s. For QBW of radius equal to 55cm, the maximum value for R_u/H_i observed was equal to 3.870at H_i/gT^2 = 7.645 x10^{-4} and at water depth equal to 35cm.The maximum value for R_d/H_i observed were 1.904 at H_i/gT^2 = 7.645 x10^{-4} and at water depth equal to 45cm for QBW of radius equal to 55cm. When wave steepness increases, waves of short wave period has less contact with curved face of QBW therefore most of the wave energy is dissipated and less energy available for runup and rundown.

In the present research an attempt has been made to find the hydrodynamic performance characteristics of emerged QBW which includes reflection, wave runup and rundown. Therefore the research can be extended to find the numerical modelling using the same parameters.

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