Wave Transmission of Submerged Inclined Serrated Plate Breakwater

Kiran Gangadhar. Shirlal

***Abstract*—**Innovative breakwaters such as floating structures, pile breakwaters and plate breakwaters are being visualized to provide ecofriendly remedies to coastal problems. In the present paper the wave transmission of a submerged serrated inclined plate breakwater is experimentally investigated. A stationary plate of length of 0.8 m and thickness 0.003m, inclined at 60^0 and a submerged at depths of 0.0 m and 0.05 m with rectangular and square fixed in zigzag and parallel configuration is tested using monochromatic waves. It is found that the plate with square zigzag serrations exhibits smallest range of K_t for the entire range of test parameters considered and is effective than a smooth plate.

***Keywords*—**Plate Breakwater, Serrations, Depth of Submergence, Wave Breaking, Wave Transmission

I. Introduction

OCEAN waves are surface water phenomena. Water particles move in circular orbits in deep water and in elliptical orbits in shallow water region due to wave motion. Major portion of the wave energy is concentrated in the surface region. Wave energy entering into a region can be reduced effectively by placing obstructions near the surface region. Inclined plate breakwater penetrates through the layers of water with dissimilar particle velocities and promotes their interaction. This causes deformation of particular orbits which will result in causing an increase in turbulence and loss of energy and wave breaking. These phenomena will further reduce the wave activity on the lee side.

Plate breakwaters are relatively eco-friendly as they allow free movement of water, sediments, pollutants, and marine organisms through the gaps of the structures above and below the plates. Since this concept was initiated [1], and [2], substantial experimental and mathematical model studies have been carried out to find their y various investigators over a period of time. These plate breakwaters could be economical where tidal variations are moderate and only partial protection from waves is required like harbor entrance, beach protection, small craft harbors etc.

The test of hydraulic behavior of horizontal plate, and vertical submerged plate showed that the incident wave steepness H/L (where, H and L are the wave height, and wave length at the site respectively), relative depth d/L, (where, d is the depth of water), and relative depth of submergence ds/d, (where, ds is the depth of top of breakwater from still water level), and relative crest width B/L (where B is the length of plate breakwater or width of crest of submerged breakwater).has an important influence in wave breaking [1].

A fully submerged inclined plate was analyzed using linear diffraction theory by the finite element method [2]. The serrated seawall improved the performance like reduction of wave reflection, run-up and run-down and wave pressures by 20 % to 40 % over its smooth counterpart [3]. Performance characteristics of horizontal and inclined plate breakwater were experimentally investigated angles of inclinations i.e. 0° and 30° with 0.50 m wide plate [4]. A comprehensive experimental study on performance characteristics of submerged smooth inclined plate breakwater revealed that, lowest transmission co-efficient (K_t) of 0.30 is observed when the plate is submerged at ds/d 0.1 to 0.2 for an angle of inclination of 60° and B/d = 0.80. This breakwater has K_t around 0.6 for the entire range of test parameters [5], and [6]. The literature studied indicated that inclined plate breakwaters can offer an ecofriendly solution to coastal engineering problems whose effectiveness can be further enhanced by introducing serrations on the plate [7]. Present paper is guided by this reasoning [8].

II. Objective of the Study

The objectives of the present experimental investigation, under selected test conditions are to:

1. determine the transmission coefficient (K_t) for a submerged inclined rough plate.
2. investigate the influence of rectangular and square serrations with zigzag and parallel orientations on K_t.

III. Experimental Details

A. Wave Flume

A two dimensional wave flume of the Marine Structures Laboratory of the Department of Applied Mechanics and Hydraulics, National Institute of Technology Karnataka, Surathkal, India is used to test the physical models of the breakwaters subjected to monochromatic waves generated in desired water depths. Fig. 1 gives a schematic diagram of the experimental setup. The wave flume is 50 m long, 0.71 m wide and 1.1 m deep. About 15 m length of the flume is provided with glass panels on one side to place the test models and facilitate photography. It has a 41.5 m long smooth concrete bed. Gradual transition is provided between normal

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bed level of the channel and that of wave generating chamber by a ramp. It has a 6.3 m long, 1.5 m wide and 1.4 m deep chamber at one end where the bottom hinged flap generate waves. The wave filter consists of a series of vertical asbestos cement sheets spaced at about 0.1 m centre to centre parallel to length of the flume. A fly-wheel and bar-chain link the motor with flap. By changing the eccentricity of bar chain on the fly-wheel the wave height can be varied for a particular wave period. The changing of frequency through inverter, waves of desired wave period can be generated.

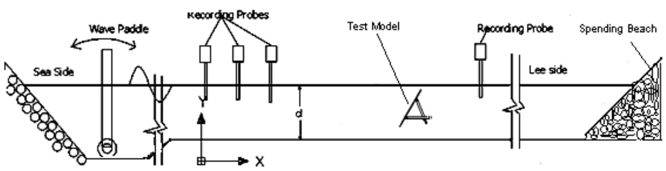

Fig. 1 Details of experimental setup

The flap is controlled by an induction motor of 11 Kw power at 1450 rpm. This motor is regulated by an inventor drive (0 – 50 Hz) rotating in a speed range of 0–155 rpm. Regular waves of 0.08 m to 0.24 m heights and periods of 0.8 s to 4.0 s in a maximum water depth of 0.5 m can be generated in this flume.

B. Instrumentation

The capacitance type wave probes along with amplification units are used for data acquisition. Four such probes are used during the experimental work, three for acquiring incident and reflected wave heights (H_i and H_r) and one for transmitted wave heights (H_t) as shown in Fig. 1. The spacing between probes is adjusted approximately to one third of the wave length to ensure accuracy as suggested by Isaacson [9]. During experimentation, signals from wave probes are verified online and recorded by the computer through the data acquisition system. These are then processed for separating the incident and reflected components using software based on the Isaacson's method.

C. Test Model

Fig. 2 shows a 1:30 scale model of a submerged stationary serrated plate of length (B) of 0.8 m and thickness 0.003m, inclined at 60^0 and depth of submergence (ds) of 0.0 m and 0.05 m. Wooden serrations of rectangular and square shapes

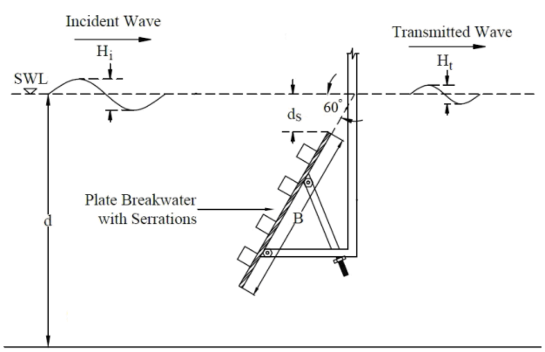

Fig. 2 Details of serrated plate breakwater model

pasted to this plate with zigzag and parallel configurations are shown in Fig. 3. The models are tested using monochromatic waves in a water depth (d) of 0.5 m. The plate is stiffened by angular steel members at longitudinal edges to get the required stiffness and to eliminate the possibility of vibrations.

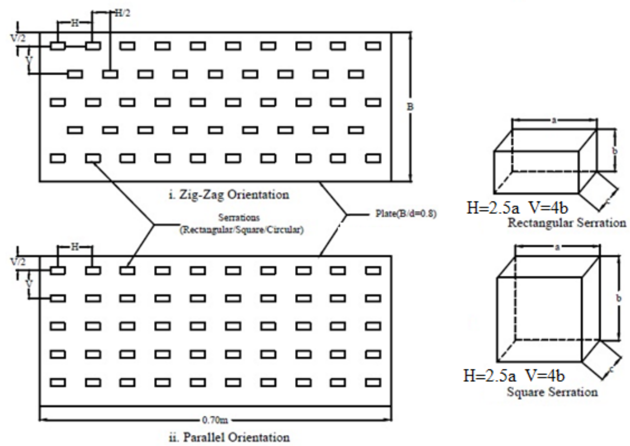

Fig. 3 Definition sketch of serrations and plate model

This test section is subjected to normal wave attack of regular waves of height (H_i) ranging from 0.05 m to 0.15 m, of period (T) varying from 1.0 s to 2.2 s in a depth of water (d) of 0.5 m. Further, wave probes record the incident wave height at 1 m seaward and the transmitted wave height (H_t) on the leeside at 1 m on the lee side. The transmission coefficient K_t is computed as the ratio of H_t and H_i.

IV. Results and Discussion

The variation wave transmission coefficient (K_t) when plotted against the deep water wave steepness parameter (H_o/gT^2) for plate with different serrations is studied through graphs.

A. Rectangular Plate

Fig. 4 shows the K_t decreasing with the increase of H_o/gT^2 for plate with rectangular shaped zigzag serrations. The overall variation of K_t is from 0.69 to 0.40 for ds/d = 0.00 and

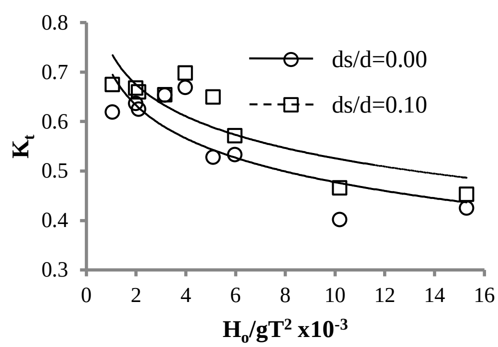

Fig. 4 K_t vs H_o/gT^2 for plate with rectangular zigzag serrations from 0.70 to 0.42 for ds/d = 0.10 for the complete range of H_o/gT^2 varying from $1x10^{-3}$ to $16x10^{-3}$ in a water depth d of 0.5 m. K_t decreases rapidly for $H_o/gT^2 > 5x10^{-3}$. This indicates that the plate structure is effective for steeper waves.

Fig. 5 shows the K_t decreasing from is from 0.66 to 0.44 for ds/d = 0.00 and from 0.73 to 0.50 for ds/d = 0.10 for the plate with rectangular parallel serrations. From Fig. 4 and Fig. 5, zigzag orientation appears efficient in reducing wave transmission.

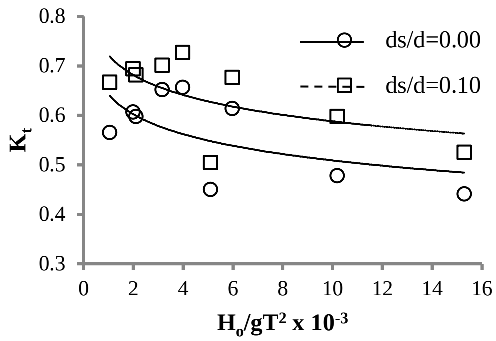

Fig. 5 K_t vs. H_o/gT^2 for plate with rectangular parallel serrations

B. Square Plate

For the plate with square zigzag serrations in the water depth 0.50 m, K_t drops from 0.69 to 0.34 for ds/d = 0.00 and from 0.65 to 0.41 for ds/d = 0.10. This is depicted in Fig. 6. This submerged plate seems to be effective as K_t drops below 0.6 [10] for $H_o/gT^2 > 4x10^{-3}$. This indicates that this plate breakwater is effective for steeper waves. The decrease of K_t is drastic for ds/d =0.00 than that for ds/d =0.10.

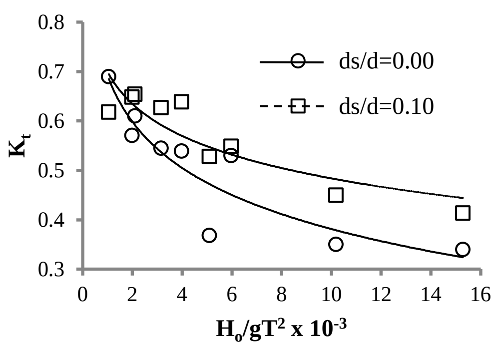

Fig. 6 Variation of K_t for a plate with square zigzag serrations

Fig. 7 shows decrease of K_t with the increase in H_o/gT^2. For the water depth d of 0.50 m, K_t drops from 0.74 to 0.42 for ds/d = 0.00 and from 0.76 to 0.45 for ds/d = 0.10. It is clear from Fig. 6 and Fig. 7, that the plate with zigzag serrations is more effective with smaller K_t.

By considering the performances of plates with rectangular and square serrations, it can be said that, the plate with square serrations with zigzag orientation is more effective in reducing wave transmission on the lee side. Smooth plate

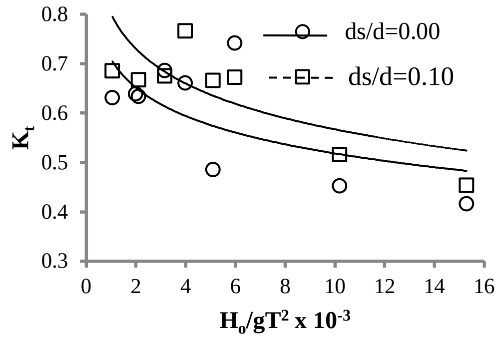

Fig. 7 Variation of K_t for a plate with square parallel serrations

C. Comparison of smooth and serrated plates

The variation of K_t with H_o/gT^2 of smooth and rough plate with square zigzag serrations are compared in Fig. 8 and Fig. 9.

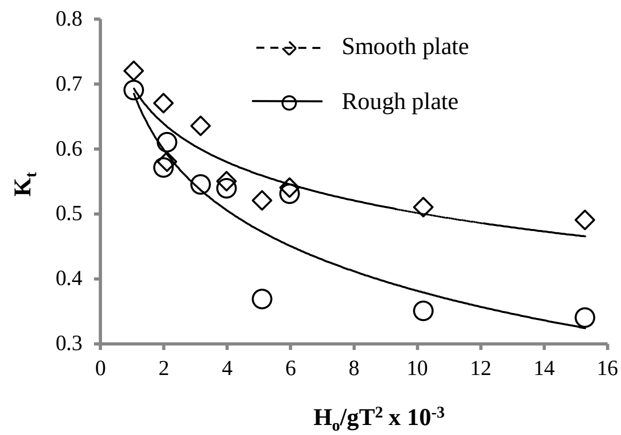

Fig. 8 Comparison of K_t of smooth and rough plate for ds/d=0.00

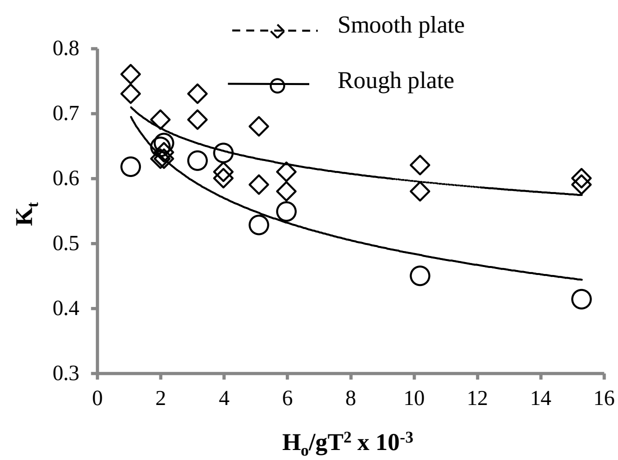

Fig. 9 Comparison of K_t of smooth and rough plate for ds/d=0.10

It is observed that overall reduction in K_t for rough plate with square zigzag serrations is up to 29 % smaller than that for smooth plate.

V. CONCLUSIONS

Following are the conclusions drawn from the present study:

1. For the submerged inclined serrated plate breakwater, K_t decreases with the increase of wave steepness parameter H_0/gT^2.
2. The plate breakwater with zigzag serrations is more effective in reducing wave transmission than the parallel serrations.
3. Square serrations are more effective in reducing wave transmission than the rectangular serrations.
4. Plate breakwater with square zigzag serrations reduces wave height transmission up to 29 % than the smooth plate.

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