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Efficacy of Beach Vegetation in Controlling Wave Run up and Rundown – an Experimental Investigation

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ABSTRACT: Vegetation is a potential ecofriendly and economically viable counter measure for beach erosion and also has additional advantages such as enhancing the aesthetics, beach conservation. Wave attenuation by vegetation is a function of vegetation characteristics such as geometry, density, stiffness, and spatial coverage as well as wave conditions such as incident wave height, period, and direction. This paper discusses experimental study on the hydraulic performance of 1:30 scale model of Casuarina Equisetifolia meadow, prepared by fixing 0.20 m long nylon rods of 0.08 m diameter at a spacing of 0.05 m c/c on a 0.04 m thick concrete slab of size 1 m × 0.73 m in regular/straight and staggered position is placed in the wave flume on the beach of slope 1V:12H at about 38m away subjected to varying wave climate. Water waves propagating through the vegetation lose energy by performing work on the vegetation stems, which directly results in smaller wave heights.

Keywords: Coastal vegetation, Nylon rod model, Regular and staggered configurations, Wave run up, Wave rundown.

1 INTRODUCTION

Coastal vegetation is a potential ecofriendly and economically viable counter measure for beach erosion by reducing wave run up and rundown. Besides this, it also has additional advantages such as enhancing the aesthetics, beach conservation, and adding to biodiversity. Moreover, coastal vegetation helps to develop sand dunes in front of the forest by trapping sand carried by the wind, which plays a significant role in beach building and taming extreme wave attack.

In the last decade there has been a growing interest in the studies which attempt to understand the impact of vegetation on flow field in the marine ecosystems (Hiraishi and Harada, 2003, Matsutomi et al. 2006, Asano et al. 2008, Cavallaro et al. 2010). This surge of interest is a new approach to a concept which tries to solve coastal and hydraulic engineering problems taking ecological balance into account. One of the primary motivations of vegetation studies is to understand related transport processes in natural environments, such as the transport of pollutants, heat, sediment, etc. Tree morphology is an important aspect when considering the wave attenuation ability of coastal forests, because attenuation results from the hydrodynamic resistance of tree components such as trunks, branches and leaves. Water waves propagating through submerged and emergent vegetation lose energy by performing work on the vegetation stems, which directly results in smaller wave heights. Wave attenuation by vegetation is a function of vegetation characteristics such as geometry, density, stiffness, and spatial coverage as well as wave conditions such as incident wave height, period, and direction. Vegetation-wave interactions are highly dynamic in that the vegetation field is exposed to variable wave forcing that changes with time as stems bend, flatten to the bed, or are washed out. As evidenced by these many dependencies and the extensive variety of coastal plants, the variability of wave damping by vegetation is large (Mendez and Losada, 2004). The reduction of run-up and inundation depth will reduce the area of destruction behind a vegetation belt in the vertical direction.

Casuarina Equisetifolia or 'Beach Sea Oak' is native to the tropical and subtropical coastlines of Australia, Southeast Asia, Malaysia, Melanesia, and Polynesia and New Caledonia and is one of the world's fastest growing (1m to 3 m per year) trees. It is a nitrogen-fixing, medium to large evergreen tree 6 m to 30 m or more in height. The tree has a thin crown of green, drooping branch lets. The narrow crown of the tree becomes irregular and spread with age. Casuarina Equisetifolia is predominantly a coastal species and has the rare property of growing upright and symmetrical on windswept coasts. The densities of the tree are 1600-10,000 trees/ha can be planted with 1m to 2.5 m between trees. Diameter of Casuarina Equisetifolia is about 0.5 m. These trees protect shorelines against erosion by making attenuating steep waves. It is concurred that beach plants are an integral part of ecofriendly shore protection techniques, and there is scarcity of information to ensure its successful design and realization and calls for further studies. The present research work involves experimental study investigation of wave transmission characteristics of simulated beach vegetation in a wave flume.

2 OBJECTIVE OF STUDY

The present study is aimed to investigate the effect of emergent vegetation on the run-up and rundown on a 1:12 sloped beach under the influence of varying wave characteristics for a given water depth for straight and staggered positions of tree trunks.

3 EXPERIMENTAL DETAILS

3.1 *Wave Flume*

The physical model is tested for monocromatic waves in a two dimensional wave flume of Marine Structures laboratory of Department of Applied Mechanics and Hydraulics, National Institute of Technology Karnataka, Surathkal, India. Figure 1 gives a schematic diagram of experimental setup. The changing of frequency through inverter, one can generate the desired wave period. A fly-wheel and bar-chain link the mortar with flap. By changing the eccentricity of bar chain on the fly-wheel one can vary the wave height for a particular wave period. The wave flume is 50 m long, 0.71 m wide and 1.1 m deep. It has a 41.5 m long smooth concrete bed. About 15 m length of the flume is provided with glass panels on one side. 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 generates waves. 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 of periods 0.8 sec to 4.0 sec in a maximum water depth of 0.5 m can be generated with this facility.

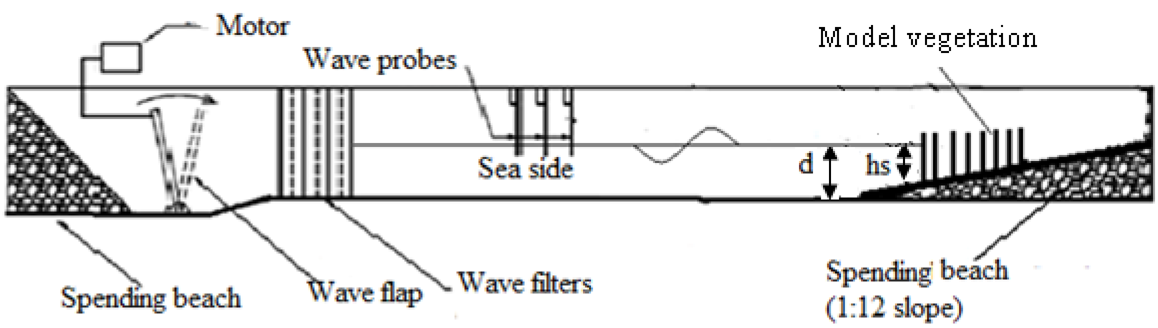

Figure 1. Details of experimental setup.

3.2 *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 wave heights (H) and one for measuring run up and run down. During the experimentation, the signals from the wave probes are acquired through a data acquisition system and recorded by the computer, which was processed using a program to yield the wave heights.

3.3 *Test Models*

The 1:30 scale test model of Casuarina Equisetifolia meadow is prepared by fixing 0.20 m long nylon rods of 0.08 m diameter at a spacing of 0.05 m c/c on a 0.04 m thick concrete slab of size 1 m × 0.73 m in regular/straight line and staggered position. The projected height of nylon rods above the slab (hs) is 0.16 m. Then models were placed in the wave flume on the beach of slope 1V:12H at about 38m away from wave flap as shown in Figure 1. The experiments are conducted for waves heights (H) of 0.08 m to 0.16 m and periods (T) of 1.4 sec to 2.5 sec generated in a constant water depth (d) of 0.4 m. The schematic diagram of the test models are shown in Figure 2.

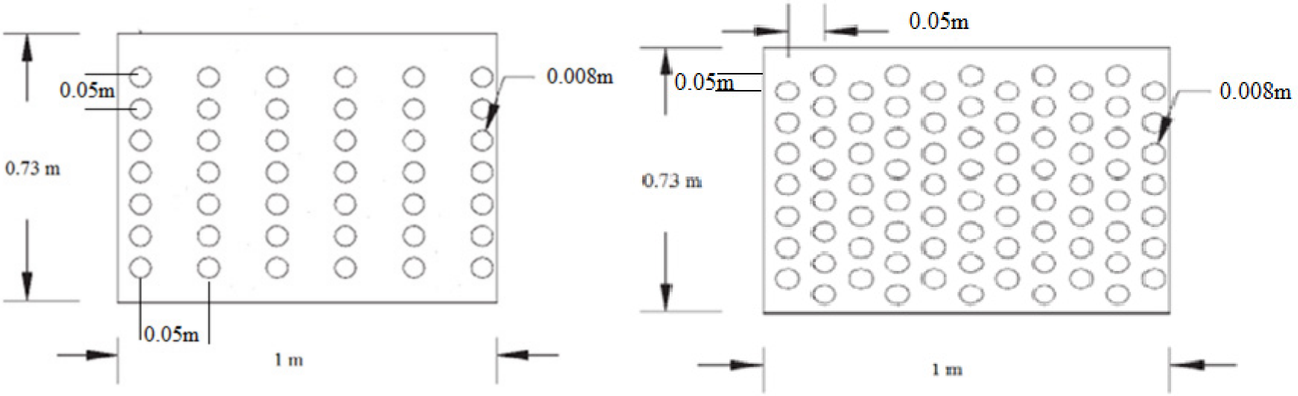

Figure 2. Schematic representation of straight and staggered arrangement of model vegetation.

3.4 *Methodology*

The wave flume was filled with fresh water to the required depth (0.40m). Before the model was tested, the flume is calibrated to produce the incident waves of different combinations of wave height and wave periods. Combinations that produced the secondary waves in the flume are not considered for the experiments. The wave probes are calibrated at the beginning and at the end of the test runs.

4 RESULTS

The data collected in the present experimental work is expressed as non-dimensional quantities. The variation of relative run up (Ru/H) and relative run down (Ru/H) for varying wave steepness parameter (H/gT^2) are studied through graphs with respect to changing straight and staggered positions of the simulated vegetation and is analysed through the graphs.

4.1 *Straight Vegetation*

4.1.1 *Effect of Wave Steepness on Run Up*

Figure 3 shows the best fit lines of Ru/H for the varying wave steepness H/gT^2. The run up decreases with the increase in wave steepness. Ru/H varies from 0.59 to 0.31 and from 0.61 to 0.36 respectively with vegetation and without vegetation for the entire range of wave steepness (H/gT^2) of 0 .0019 to 0.0069.

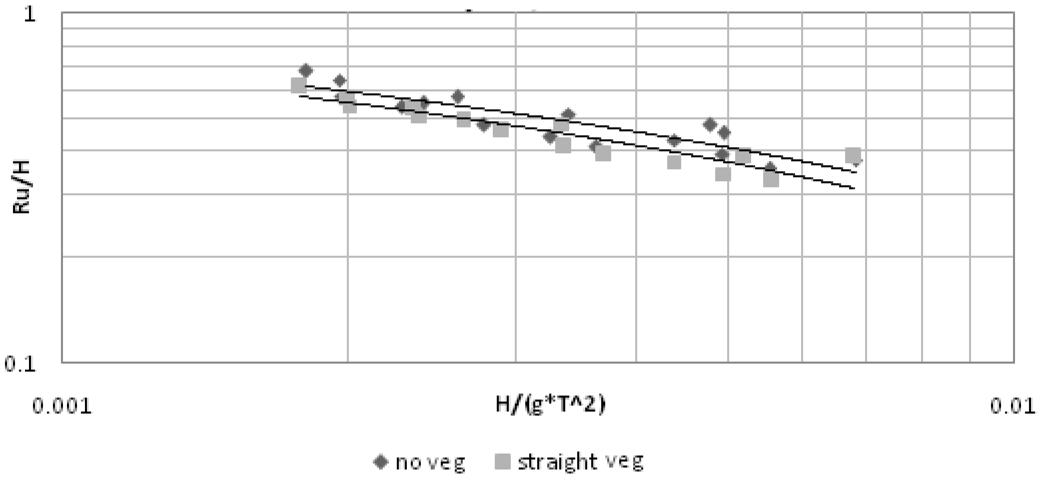

Figure 3. Variation of Ru/H with H/gT^2.

4.1.2 *Effect of Wave Steepness on Run Down*

Variation of Rd/H with H/gT^2 is illustrated in Figure 4. It is observed that, the run up decreases with the increase in wave steepness parameter. Rd/H decreases from 0.51 to 0.19 and from 0.61 to 0.19 with vegetation and without vegetation respectively for the entire range of wave steepness parameter.

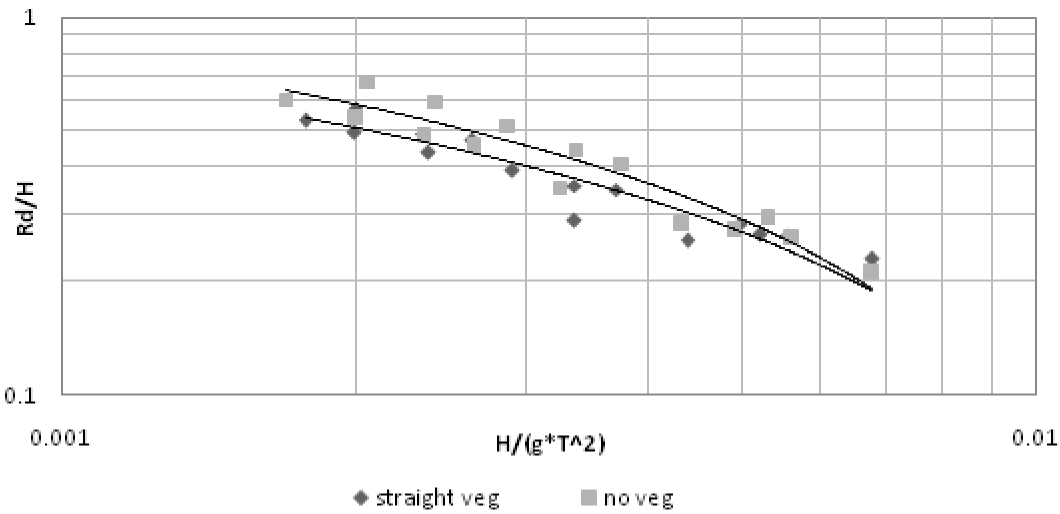

Figure 4. Variation of Rd/H with H/gT^2.

4.2 *Staggered Vegetation*

4.2.1 *Effect of Wave Steepness on Run Up*

In Figure 5 the best fit lines for variation of Ru/H with the wave steepness parameter H/gT^2 are shown without vegetation and with staggered vegetation. Ru/H varied from 0.61 to 0.36 and from 0.6 to 0.28 respectively without and with vegetation.

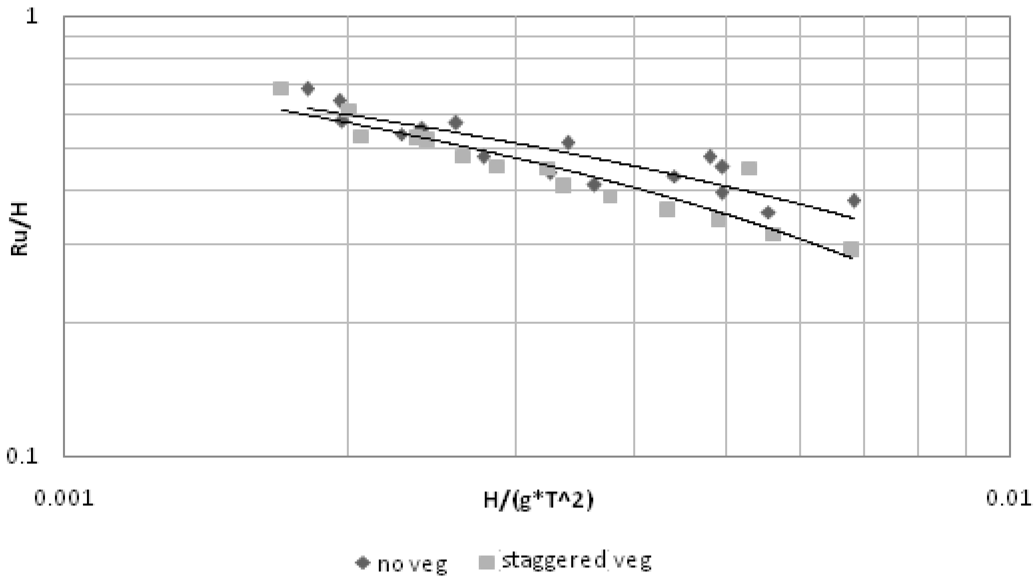

Figure 5. Variation of Ru/H with H_o/gT^2.

4.2.2 *Effect of deep water wave steepness on damage level*

Figure 6 exhibits the best fit lines for variation of relative run down Rd/H with the wave steepness parameter H/gT^2 without vegetation and with staggered vegetation. Rd/H, decreases from 0.61 to 0.19 and from 0.46 to 0.14 respectively without and with vegetation while wave steepness parameter H/gT^2 increases from 0 .0019 to 0.0069.

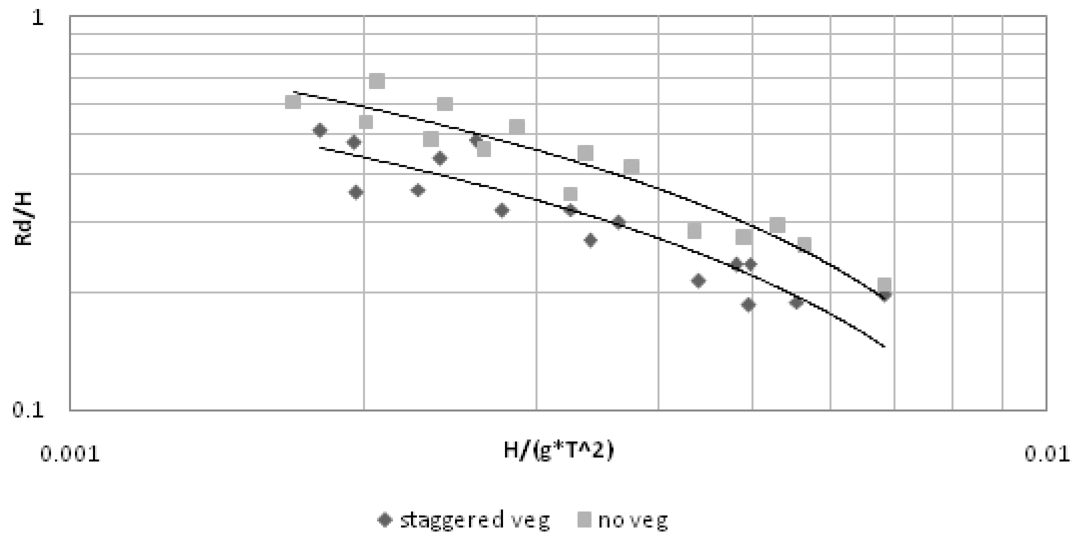

Figure 6. Variation of Rd/H with H_o/gT^2.

4.3 *Comparison of Straight and Staggered Vegetation*

In Figures 7 and 8, the best fit lines show the variation of Ru/H and Rd/H with the wave steepness parameter H/gT^2 for straight and staggered vegetation respectively. Ru/H varied from 0.6 to 0.3 and from 0.6 to 0.28 respectively as shown in Figure 7. This indicates that both the straight and staggered vegetation almost have similar impact on wave run up.

Figure 8 observes that, Rd/H varies from 0.53 to 0.19 and from 0.46 to 0.14 for straight and staggered vegetation respectively. This indicates that, the staggered vegetation is relatively more efficient in reducing run down than the straight vegetation.

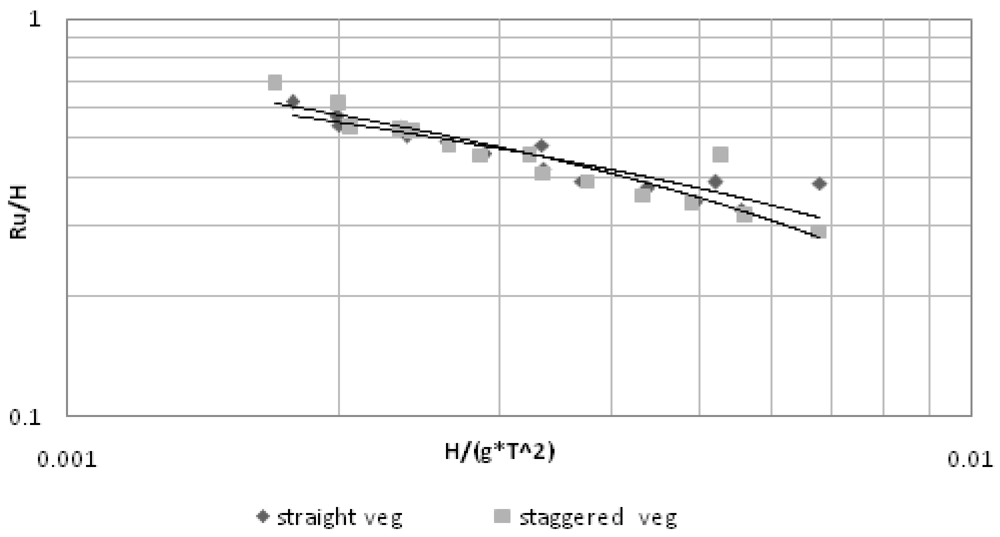

Figure 7. Variation of Ru/H with H_o/gT^2.

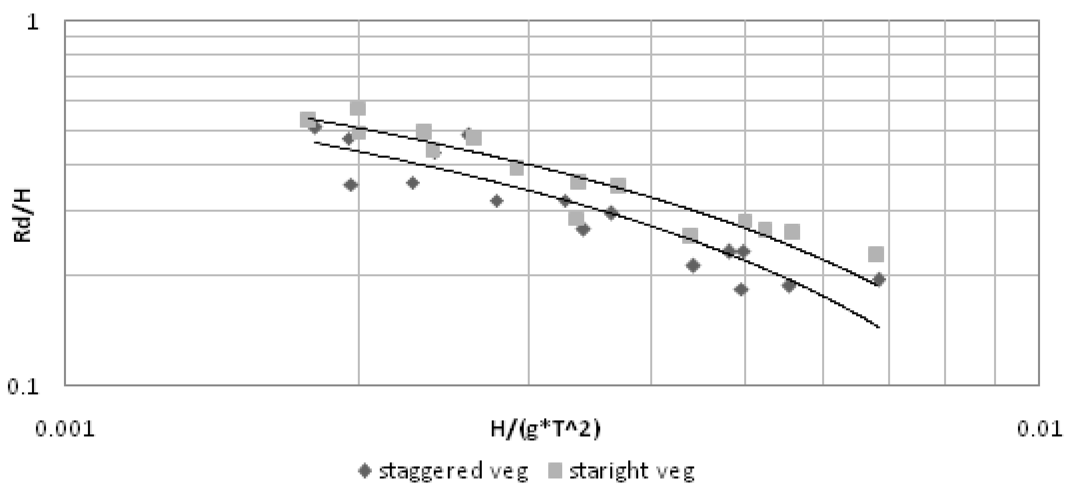

Figure 8. Variation of Rd/H with H_o/gT^2.

5 CONCLUSIONS

Based on the present experimental investigation, the following conclusions are drawn.

1) Relative wave run up (Ru/H) varied from 0.61 to 0.36 over the plain beach slope. While it varied between 0.6 and 0.3 for the both the straight and staggered configuration of vegetation indicating almost similar influence on wave run up.
2) For a plain beach, the relative wave run down (Rd/H) varied between 0.61 and 0.19. While, it dropped from 0.51 to 0.19 and from 0.46 to 0.14 for the straight and staggered beach vegetation respectively.
3) The beach vegetation is effective in controlling wave run up and rundown and hence it may be considered as a measure for beach erosion depending upon the site conditions.

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