HENRY
Hydraulic Engineering Repository

Ein Service der Bundesanstalt für Wasserbau

Conference Paper, Published Version

Rao, Subba; Shirlal, Kiran G.; Varghese, Roobin V.; Santhosh D. C., S.

Physical Model Study of Inclined Twin Plate Submerged Breakwater

Zur Verfügung gestellt in Kooperation mit/Provided in Cooperation with:
Kuratorium für Forschung im Küsteningenieurwesen (KFKI)

Verfügbar unter/Available at: https://hdl.handle.net/20.500.11970/109906

Vorgeschlagene Zitierweise/Suggested citation:
Rao, Subba; Shirlal, Kiran G.; Varghese, Roobin V.; Santhosh D. C., S. (2010): Physical Model Study of Inclined Twin Plate Submerged Breakwater. In: Sundar, V.; Srinivasan, K.; Murali, K.; Sudheer, K.P. (Hg.): ICHE 2010. Proceedings of the 9th International Conference on Hydro-Science & Engineering, August 2-5, 2010, Chennai, India. Chennai: Indian Institute of Technology Madras.

Standardnutzungsbedingungen/Terms of Use:

Die Dokumente in HENRY stehen unter der Creative Commons Lizenz CC BY 4.0, sofern keine abweichenden Nutzungsbedingungen getroffen wurden. Damit ist sowohl die kommerzielle Nutzung als auch das Teilen, die Weiterbearbeitung und Speicherung erlaubt. Das Verwenden und das Bearbeiten stehen unter der Bedingung der Namensnennung. Im Einzelfall kann eine restriktivere Lizenz gelten; dann gelten abweichend von den obigen Nutzungsbedingungen die in der dort genannten Lizenz gewährten Nutzungsrechte.

Documents in HENRY are made available under the Creative Commons License CC BY 4.0, if no other license is applicable. Under CC BY 4.0 commercial use and sharing, remixing, transforming, and building upon the material of the work is permitted. In some cases a different, more restrictive license may apply; if applicable the terms of the restrictive license will be binding.

Proceedings of ninth International Conference on Hydro-Science and Engineering (ICHE 2010), IIT Madras, Chennai, India.
2 - 5 August 2010

PHYSICAL MODEL STUDY OF INCLINED TWIN PLATE SUBMERGED BREAKWATER

Subba Rao[1], Kiran G. Shirlal[2], Roobin V. Varghese[3], S. Santhosh D.C.[4]

Abstract:-This paper explains the results of physical model studies conducted in a monochromatic wave flume, to evaluate the wave transmission characteristics of a submerged plate breakwater consisting of a pair of identical fixed plates of 0.40m length and 0.003m thickness. The model was oriented at an angle of inclination of 60^0 and submergence ratio of 0.0 and 0.1. The spacing of plate was varied from 0.05m to 0.55m. The influence of wave steepness, submergence and spacing between the plates on wave transmission, reflection and energy loss were analysed. It was found that the breakwater consisting of twin inclined plates is good enough to reduce wave height by 40%, for waves with steepness parameter higher than $3x10^{-3}$. The system performs better when the upper edge of the plates are at the still water level. The values of K_t reduce and the loss of energy increase with increase of spacing between the plates. Hence the inclined twin plate breakwater with an angle of inclination of 60^0 and relative spacing of 0.9 to 1.1 can be considered for partial wave attenuation.

INTRODUCTION

Focus of research on coastal protection is shifting from the hard measures to ecologically acceptable solutions with optimal usage of construction materials. Floating structures, pile breakwaters and horizontal plate breakwaters were investigated by various researchers. The minor ports and fishing harbours can use partial wave barriers as they can tolerate a certain amount of wave activity within the basin. Tourist places, recreational and water sporting areas and aquaculture locations need to maintain wave activity in a preset level throughout the year. A structure located near the water surface is known to be effective in bringing down the wave activity behind it since the energy of the waves is concentrated in the region close to the surface. Investigations have shown that a horizontal plate fixed at the surface or slightly below the surface can cause considerable wave attenuation due to frictional resistance and wave breaking. Inclined plate breakwater is found to be more effective than the horizontal one, since it penetrates

---

Professor, [2]Associate Professor, [3]Research Scholar, [4]P.G. Student, Department of Applied Mechanics and Hydraulics, National Institute of Technology Karnataka, Surathkal Srinivasnagar D. K. District, Karnataka, India- 575025. e-mail 1. surakrec@gmail.com, ***2.*** kshirlal@gmail.com 3. roobin99@gmail.com 4. illuminatidc@gmail.com

through the layers of water with dissimilar particle velocities and promotes their interaction. (Nallayarasu et. al, 1994, Subba Rao et al., 2007, 2009).

The steep waves acting in a region are known to be one of the primary reasons behind the severe coastal erosion at some locations. Dattatri et al. (1978) reported that a plate breakwater can induce breaking of the steep waves. The optimum value of relative depth of submergence (ds/d, where ds is the depth of the top of breakwater from still water level) may vary from 0 to 0.2.

A general solution for the problem of wave scattering on a fixed horizontal plate was attempted by Patarapanich (1984) using finite element method. Cheong and Patarapanich (1992) conducted a theoretical analysis of double plate system and derived transmission coefficients. It was observed that the lowest wave transmission occurs when ds/d is about 0.10 to 0.20 and the corresponding transmission coefficient (K_t) is in between 0.3 to 0.5. Neelamani and Reddy (1992) conducted an experimental study and found that the horizontal plate at the surface provides the least values of K_t. Nallayarasu et al. (1994) analysed a fully submerged inclined plate using linear diffraction theory using FEM. Wang and Shen (1999) conducted mathematical model analyses of multiple plate breakwaters and reported that the minimum value of $K_t = 0.78$ was when $B/L = 0.32$ (where, B is the length of the plate and L is the wave length) and $ds/d = 0.25$. Neelamani and Vedagiri (2002) carried out physical model studies on twin vertical barrier using uneven plates for developing an eco-friendly breakwater and found that the transmission decreases with the depth of immersion and wave steepness. A twin plate breakwater system consisting of a pair of identical horizontal plates with one plate at the surface and other just below it was investigated analytically using the linear potential wave theory (Usha and Gayatri, 2005). The K_t values reduced with increase in relative submergence (d/L) for all values of spacing (s) between the plates. The optimum relative spacing of $s/d = 0.23$ and the relative width of plate ranged between 0.37 and 0.39 were optimum which resulted in K_t values ranging from 0.2 to 0.4. The performance of the twin plate system was better than that of the single surface plate breakwater and single submerged plate breakwater.

Physical model studies on a single surface plate breakwater and twin plate breakwater with regular and random waves have shown that the wave transmission decreased corresponding to the increase in B/L ratio (Neelamani and Gayathri, 2006). The values of K_t varied between 0.1 and 0.7 for variations of B/L from 0.18 to 0.84 and s/d from 0.5 to 0.40. Multiple-layered breakwater consisting of several horizontal plates was tested using physical models under a regular wave environment (Wang et al., 2006). The transmission coefficient decreased with increase in the relative plate width (B/L). K_t was below 0.5 for $B/L > 0.25$ which indicated that the multiple layer plate breakwater can dissipate the wave energy significantly. K_t was found to decrease with an increase in wave steepness (H/L).

Subba Rao et al. (2007, 2008a,b, 2009) carried out physical model studies on plate breakwater consisting of a thin plate with varying inclinations and reported that a plate with an angle of inclination of 60^0 is effective for waves with steepness parameter (H_0/gT^2) higher than $5x10^{-3}$.

It is felt that the use of multiple plates may improve the performance of the inclined plate breakwater and enhance its applicability to waves of low steepness. Hence a physical model study on a breakwater consisting of a pair of identical plates separated by different relative spacing and oriented at an inclination of 60^0 is attempted.

OBJECTIVES

The objectives of the present experimental investigation are to:

a) Study the wave transmission characteristics of a fixed twin plate breakwater with an angle of inclination of 60^0 under varying wave characteristics and water depth fluctuations.

b) Investigate the influence of the spacing between the plates on transmission, reflection and loss coefficients.

EXPERIMENTAL PROCEDURE

The experiments were carried out in a long wave flume with a paddle type monochromatic wave maker. The waves passed through a filter made up of thin parallel vertical plates to produce smooth waves by reducing turbulence. The incident and reflected wave characteristics (H_i, H_r) were recorded by three wave probes. The waves then propagated towards the plate breakwater model. The transmitted wave characteristics were measured by a wave probe fixed on the lee side. The data were recorded in a computer and analysed for estimating the influence of spacing of plates and steepness of waves on values of K_t, K_r and K_l, where

$$K_t = H_t / H_i \quad \ldots\ldots (1)$$

$$K_r = H_r / H_i \quad \ldots\ldots (2)$$

$$K_l = \sqrt{1 - K_t^2 - K_r^2} \quad \ldots\ldots (3)$$

Wave Flume

Fig. 1 shows the two-dimensional wave flume wherein physical model studies of the submerged plate breakwater were conducted. The flume is 50m long, 0.71m wide and 1.1m deep and has a smooth concrete bed for a length of 42m with a 6m long wave-generating chamber at one end and a beach of slope 1V:10H consisting of rubbles at the other end. The flume is provided with a bottom-hinged flap-type wave generator operated by an 11kW, 1450 rpm induction motor which is regulated by an inverter drive (0–50 Hz) so as to rotate at variable speed of 0 to 155 rpm. The system can generate monochromatic waves with a wave height ranging from 0.02 to 0.24m and periods ranging from 0.8 to 4s in a maximum water depth of 0.5 m.

Physical Model

The model of plate breakwater was constructed using two smooth steel plates of 3.0mm thickness and 0.40m length (B) and tested in a depth of water of 0.5m i.e. B/d = 0.8. The plates were stiffened by steel angular members at longitudinal edges to get the required stiffness and to eliminate the possibility of vibrations. This system was then supported by steel flats from the top to provide stability against oscillations. The model was raised or lowered accordingly using adjustable screws at the top of the supporting structure to achieve a required depth of submergence and inclination. The experiments were carried out with a depth of submergence of 0.0 and 0.05m with angle of inclination of 60^0 with respect to the horizontal as shown in Fig. 1. The horizontal spacing between the plates was varied from 0.05 to 0.55m. The set up provided bottom clearance of about 20% of the water depth to ensure exchange of water across the breakwater.

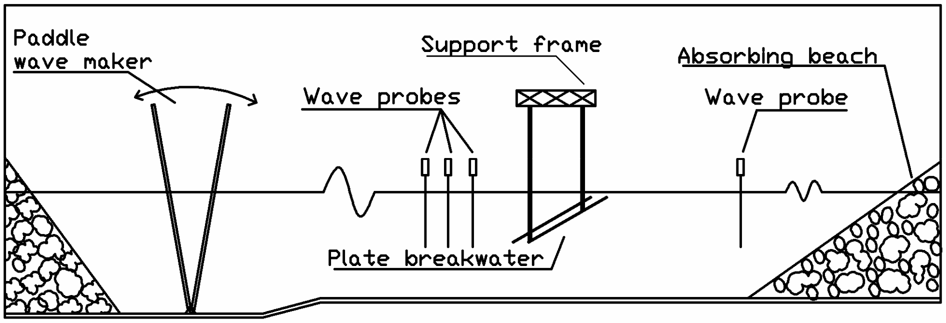

Fig. 1 Schematic diagram of experimental set up and plate breakwater

Data Acquisition

Four capacitance-type wave probes along with amplification units were used for data acquisition, three for acquiring incident and reflected wave characteristics (H_i and H_r) and one for transmitted wave characteristics (H_t) as shown in Fig.1. During the experimentation, the signals from the wave probes were acquired through a data acquisition system and recorded by the computer, which was processed using a program to yield the incident and reflected wave heights.

Calibration of the Experimental Set-up

The wave flume was filled with fresh water to the required depth (0.50m). Before the model was tested, the flume was calibrated to produce the incident waves of different combinations of wave height and wave periods. Combinations that produced the secondary waves in the flume were not considered for the experiments. The wave probes were calibrated at the beginning and at the end of the test runs.

RESULTS AND DISCUSSION

Variation of Transmission

The variation of K_t with respect to H_0/gT^2 for relative spacing (s/d) values from 0.1 to 1.1 when ds/d = 0, is shown in Fig.2. In the case of the single plate, the values of K_t decreases from 0.71 to 0.46 with increase of H_0/gT^2 from $1x10^{-3}$ to $16x10^{-3}$. K_t reduces marginally in case of twin plate with s/d=0.1, but the variation is not uniform for all the values of H_0/gT^2. As the spacing increases, the values of K_t decreases. The maximum variation of K_t is from 0.63 to 0.26 when s/d = 1.1. K_t is below 0.6 for $H_0/gT^2 > 3x10^{-3}$ when s/d ≥ 0.9. For twin plate with s/d ≥ 0.9, K_t is 10 % to 50% lower than that of the single plate.

Fig.3 shows the variation of K_t with H_0/gT^2 for ds/d=0.1, for s/d varying from 0.1 to 1.1. There is very little difference in the values of K_t when the plates are closely spaced (s/d 0.3) and the behaviour of the twin plates is similar to that of the single plate. Further increase of spacing improves the effectiveness of the plate breakwater system. K_t varies from 0.72 to 0.46 as H_0/gT^2 varies from $1x10^{-3}$ to $16x10^{-3}$, which is about 3% to 22% lower than those of the single plate. The K_t is below 0.6 for for $H_0/gT^2 > 3x10^{-3}$ when s/d ≥0.9.

The transmission increases as the submergence increases since more energy is allowed to pass above the crest of the breakwater. The increase spacing provides greater crest width of the breakwater system which results in lower transmission. The average increase in K_t due to increase in submergence is about 0.11(24%). The system is applicable for coastal protection works for sites where the tidal variation is moderate since sufficient amount of wave attenuation is maintained when ds/d = 0 and when ds/d = 0.1.

Variation of Reflection

Fig. 4 and Fig.5 shows the variation of reflection coefficient with respect to H_0/gT^2 for s/d varying from 0.1 to 1.1 in the cases of ds/d = 0 and ds/d = 0.1 respectively. K_r varies from 0.34 to 0.46 for ds/d = 0 and from 0.36 to 0.42 for ds/d = 0.1 respectively. It is noted that the influence of H_0/gT^2 is negligible in both cases. There is no significant change in the values of K_r for twin plate when compared with that of single plate. Further there is very little change of K_r due to the increase of spacing. This may be due to the fact that the reflection from the structure depends primarily on its projected area which obstructs the wave field and the increase of horizontal spacing does not significantly contribute to the increase of projected area in vertical plane.

Variation of Energy Loss

The energy loss is expressed in terms of coefficient of loss (K_l) derived from the energy conservation principle as shown in equation (3). Fig.6 and Fig. 7 shows the variation of

K_l with H_0/gT^2 for s/d varying from 0.1 to 1.1 in the cases of ds/d = 0 and ds/d = 0.1 respectively. It varies from 0.61 to 0.78 and from 0.54 to 0.73 for ds/d=0 and ds/d=0.1 respectively in the case of single plate. K_r shows sharp increase till the steepness parameter of 3x10-^{3} and gradual increase there after for both single and twin plates. It increases with increase of spacing which can be attributed to the increase in turbulence due to greater width of breakwater. High values of K_l for waves with steepness parameter above $3x10^{-3}$ observed when s/d ≥ 0.9 for both cases of submergence emphasise the potential of this breakwater system as a coastal protection measure.

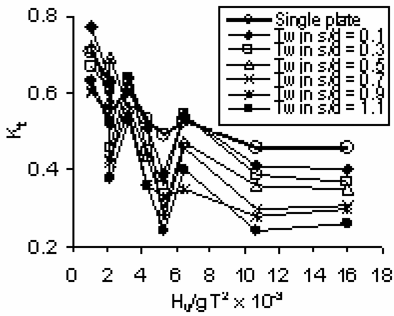

Fig. 2 K_t vs H_0/gT^2 for ds/d=0

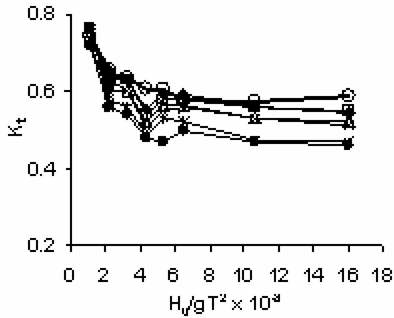

Fig. 3 K_t vs H_0/gT^2 for ds/d=0.1

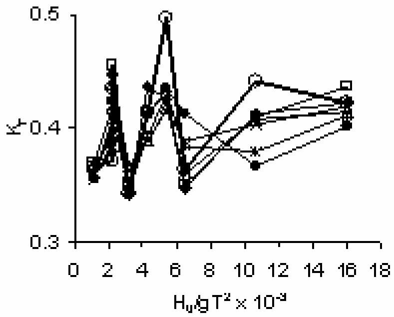

Fig. 4 K_r vs H_0/gT^2 for ds/d=0

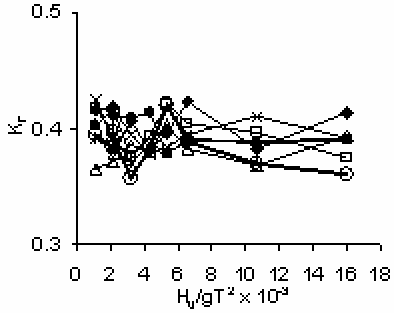

Fig. 5 K_r vs H_0/gT^2 for ds/d=0.1

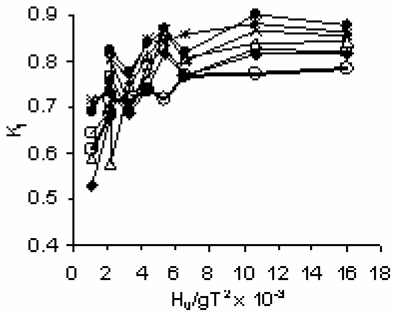

Fig. 6 K_l vs H_0/gT^2 for ds/d=0

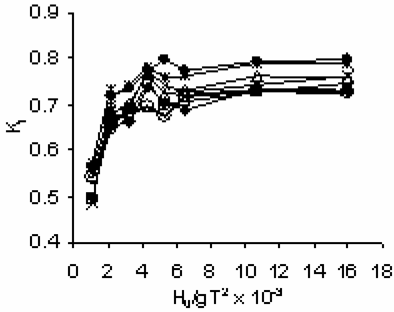

Fig. 7 K_l vs H_0/gT^2 for ds/d=0.1

CONCLUSIONS

Through the current physical model studies the following conclusions evolved:

- The K_t decreases and K_l increases with increase of wave steepness, where as the K_r does not show significant variation.
- The K_t values decrease and K_l values increase with increase of spacing.
- Though K_t, K_l and K_r exhibited volatility initially it decreased for $H_0/gT^2 > 8x10^{-3.}$
- In the cases of both the single plate and the twin plate breakwater system, K_t increases with increase of submergence.
- The inclined twin plates system performs better than the inclined single plate.
- The twin plate breakwater system with $s/d \geq 0.9$ is suitable for partial reduction of wave height by 40% for waves with steepness parameter greater than $3x10^{-3}$ where water depth variation due to tides is not more than 10% of the depth available.

REFERENCES

Cheong H. F. and Patarapanich M., (1992). Reflection and transmission of random waves by a horizontal double-plate breakwater. Coastal Eng., (18) 63 – 82.

Dattatri, J., Raman, H. and Shankar, N. J., (1978). Performance characteristics of submerged breakwater. 16th International Conference on Coastal Engineering, Hamburg, ASCE, 2153 – 2171.

Gayathri, T., (2003). Wave interaction with twin-plate breakwater, MS Thesis, Department of Ocean Engineering. IIT, Madras.

Nallayarasu S., Cheong H. F. and Jothi Shankar N., (1994) Wave induced pressures and forces on a fixed submerged inclined plate. Jr. of Finite Elements in Analysis and Design, (18) 289-299.

Neelamani S. and Gayathri T., (2006). Wave interaction with twin plate wave barrier. Ocean Eng., (33) 495–516.

Neelamani, S., Reddy, M.S., (1992). Wave transmission and reflection characteristics of a rigid surface and submerged horizontal plate. Ocean Eng. 19 (4) 327–341.

Neelanani, S., Vedagiri, M., (2002). Wave interaction with partially immersed twin vertical barrier. Ocean Eng., (29) 215–238.

Patarapanich, M., (1984). Maximum and zero reflection from submerged plate. Journal of Waterway, Port, Coastal Ocean Eng., (110) 171 – 181.

Subba Rao, Shirlal K G, Roobin V. Varghese and K R Govindaraja, (2008) Plate breakwater a comparative study of regular and reverse inclinations. Proc. National Conference Focussing on Advances in Civil Engineering, TKMCE , Kollam, India, March 2008,159 –165.

Subba Rao, Shirlal K G, Roobin V. Varghese and S. Prashanth, (2009) Wave forces and performance of submerged plate breakwater through physical model study. Proc. International Conference in Ocean Engineering, ICOE 2009, IIT Madras, Chennai, India, February 2009, 109–110

Subba Rao, Shirlal K G., Roobin V. Varghese and K R Govindaraja, (2007) Plate breakwater as a concept of innovative alternative to submerged breakwater, Proc. Indian National Conference on Harbour and Ocean Engineering, (INCHOE-2007), NITK, Surathkal, India, December 2007, 361–367.

Subba Rao, Shirlal K G., Roobin V. Varghese and K R Govindaraja, (2007) Physical modelling of submerged plate breakwater. Proc. Indian National Conference on Hydraulics (HYDRO-2007), SVNIT Surat, India, December 2007, 538–543.

Subba Rao, Shirlal K. G., Roobin V Varghese, (2008) Physical model studies of inclined plate breakwater. Proc. of the NITK-KU Joint Seminar: Recent Advances in Engineering & Technology, Kagoshima University, Japan. December 2008, 138–144.

Usha R. and Gayathri T., (2005). Wave motion over a twin-plate breakwater. Ocean Engineering, (32) 1054 – 1072.

Wang, K.H. and Shen, Q., (1999). Wave motion over a group of submerged horizontal plates. International Journal of Engineering Science, (37) 703 – 715.

Wang, Y., Wang, G. and Li, G., (2006). Experimental study on the performance of the multiple-layer breakwater. Coastal Eng., (33) 1829 – 1839.