

TWO-DIMENSIONAL RUBBLE-MOUND BREAKWATER MODEL USING TETRAPOD AT ARMOR LAYER AND GEOTUBE AT CORE LAYER

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Abstract

Waves and currents can remove sand from the coastal areas that caused beach erosion. Beach erosion needs to be handled by building breakwater. Rubble mound breakwater is chosen to dissipate the wave energy. Rubble mound structures are widely used throughout the world; so naturally, stability tests of rubble mound structures are the most frequently conducted coastal structure model. Two-dimensional rubble mound structure physical model is carried out in a flume. The armor layer facing the seaward uses tetrapods that are placed randomly and the core layer is set to be stable by using geotube. Three different slopes of rubble mound model facing the seaward is applied, i.e., 1:1.5, 1:2, and 1:2.5, respectively. There are also four different water levels used, i.e., 38 cm, 54 cm, 63 cm, and 70 cm. The measured parameters of this study are the wave height and wave period in front of and behind the breakwater structure. The analysis that can be done is the wave absorber and transmission waves. The stability of the structure can be observed in the form of displacement armor testing on the breakwater and at toe for a wide variety of slope and water level variations.

Keywords: breakwater, geotube, physical model, rubble mound structure, tetrapod

Presenting Author's biography



Olga Pattipawaej. She is currently an undergraduate lecturer at Civil Engineering Department, Faculty of Engineering, Universitas Kristen Maranatha, Bandung, Indonesia. She received her doctorate degree from Ocean Engineering Program, Civil Engineering Department, Texas A&M University, College Station, Texas, USA. Her research is focused on evaluation of coastal vulnerability assessment and coastal management. Her research is also dealing with numerical analysis and analysis of physical model on coastal structures.

1. Introduction

Beach erosion is the erosion of soil or rock that occurs when waves and currents remove soil or rock from the beach system. The loss of soil or rock causes the beach to become gradually eroded. Beach erosion also threatens coastal properties and infrastructure such as roads, homes, and businesses. If beach erosion is left untreated, there will be degradation, reducing the ability of the soil to bind the particles that cause the sliding of land on the seaside.

Breakwater is a structure on the coast to protect the coast against erosion. Type of breakwater structure used is usually determined by the availability of materials in or near the work site, the sea conditions, water depth, and the availability of equipment for the implementation of the work. Rubble mound breakwaters use structural voids to dissipate the wave energy. Rock or concrete armor units on the outside of the structure absorb most of the energy, while gravels or sands prevent the wave energy's continuing through the breakwater core.

The prediction of rubble mound breakwaters' stability is one of the most important issues in coastal and maritime engineering. Optimizing a rubble mound structure often can only be achieved by systematic physical model tests. In this paper, two-dimensional rubble mound structure physical model is carried out in a flume at Balai Pantai. Tetrapod is placed randomly at the armor layer of rubble mound structure model that facing the seaward. The core layer of rubble mound structure model is conditionally stable by using geotube. Three different slopes of rubble mound model facing the seaward is applied, i.e., 1:1.5, 1:2, and 1:2.5, respectively. There are also four different water levels used, i.e., 38 cm, 54 cm, 63 cm, and 70 cm. The measured parameters of this study are the wave height and wave period in front of and behind the breakwater structure. The analysis that can be done is the wave absorber and transmission waves. The stability of the structure can be observed in the form of displacement armor testing on the breakwater and at toe for the variety of slope and water level variations.

2. Rubble Mound Structure

Coastal structures are intended to protect shoreline or navigation channels from the effects of waves and other hydrodynamic force. The design of coastal structures must consider a range of wave heights and periods combined with water level variations. The most common types of coastal structures are rubble mound structures, impermeable sloping structures, vertical wall structures, composite structures, floating structures, and pneumatic and hydraulic breakwaters [4].

Rubble mound structure is used extensively for breakwaters, jetties, revetments, seawalls, and wave absorber. Rubble mound structures have a core of quarry-run stones, sand, slag, or other suitable materials protected from waves action by one or more stone under layers and a core layers of relatively large, selected quarry stones or specially-shaped concrete armor units [3]. Fig. 1 shows a typical cross section of a rubble mound breakwater. The core, shown in the cross section is usually composed of sand fill, and the armor layers are made up of more rock or the concrete armor units [2].

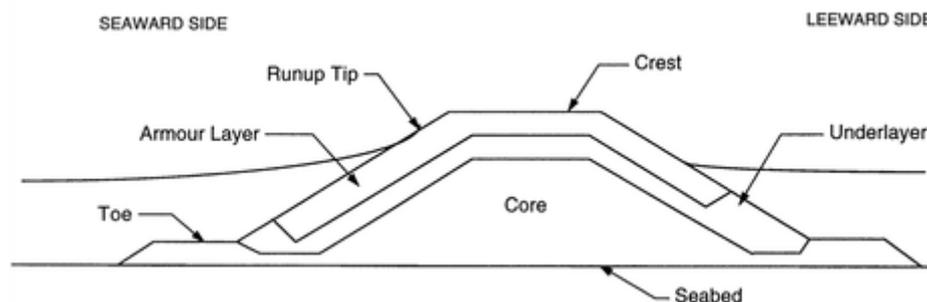


Fig. 1 Cross section of a typical rubble mound breakwater

In this paper, the armor layers use tetrapod that is a tetrahedral concrete structure used as armor unit on breakwaters (Fig. 2). A tetrapod's shape is designed to dissipate the force of incoming waves by

allowing water to flow around rather than against it and to reduce displacement by allowing a random distribution of tetrapods to mutually interlock. The core layer is set stable by using geotube. Geotube is a sand material filled geotextile tube made of permeable but soil-tight geotextile (see Fig. 3).



Fig. 2 Tetrapod Model



Fig.3 Geotube Breakwater

3. Experiment Set Up and Procedure

The experimental research was carried out in the wave flume of Laboratory Balai Pantai, Buleleng Bali. The wave flume is 40 m long, 0.6 m wide and 1.2 m high. It is equipped with a piston type wave generator that produces regular wave. Three wave probes are installed in the wave flume (Fig. 4).

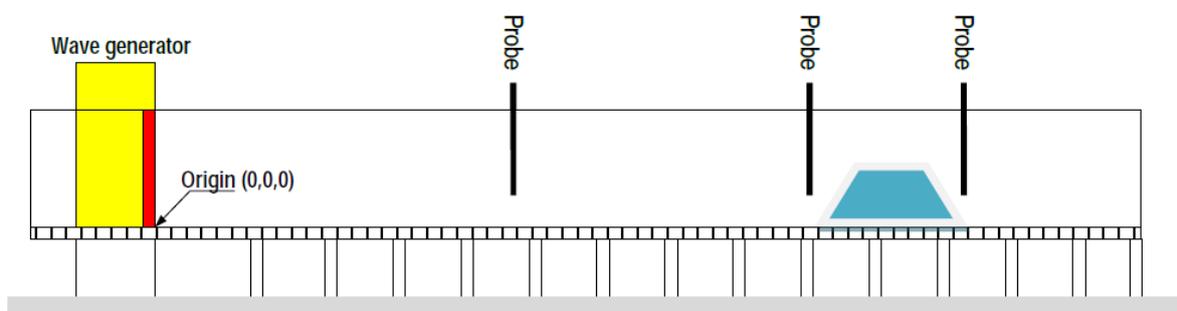


Fig. 4 Side View of the Flume

The armor units use Tetrapod with the average mass of 280 g, the relative density of 2.054 g/cm^3 , and K_d is 8. The tetrapod is randomly placed at the armor layer. The core layer is set to be stable by using geotube. Three variation of slopes facing the sea side of the breakwater model are applied, i.e., 1:1.5, 1:2, and 1:2.5, respectively. The wave period is 2 sec. The wave height for different slope of breakwater models can be seen in Tab 1. Fig. 5 presents the side view of the rubble mound breakwater

model with the slope 1:1.5. The rubble mound breakwater model is designed based on stability of rubble mound structure using Hudson formula [1]. The similarity of the rubble mound breakwater model is 1:10.

Tab. 1 Wave height at different slope of breakwater model

Slope	Wave Height (cm)
1:1.5	12.42
1:2	13.66
1:2.5	14.72



Fig. 5 Side view of rubble mound breakwater model with slope 1:1.5

The water levels are conducted at four different water levels: 38 cm (mean low water level), 54 cm (mean high water level), 63 cm (crest elevation), and 70 cm (submerged).

4. Result and Discussion

Wave direction, either normally incident or oblique, refers to the direction of wave travel with respect to the breakwater axis [2]. The significant wave height is usually defined as the average of one-third highest wave ($H_{1/3}$). Tab. 2 presents the significant wave height, runup, and rundown at 38 cm of water elevation. It can be concluded that $H_{1/3}$ and $R_u - R_d$ at the mean low water level show the smallest results at the slope 1:2.5 of the rubble mound breakwater model. It means that the highest energy of waves absorb at the slope 1:2.5 of the rubble mound breakwater model.

Tab. 2 Significant wave height, runup and rundown at 38 cm of water elevation

Format of Slope	$H_{1/3}$ (cm)	Runup, R_u (cm)	Rundown, R_d (cm)	$R_u - R_d$ (cm)
1:1,5	0.131	19.5	6.5	13.0
1:2	0.126	20.0	9.0	11.0
1:2,5	0.116	20.5	18.5	2.0

When the water level is 54 cm or at the mean high water level, there is only rundown occurred. The rundown for each different slope of rubble mound breakwater model can be seen in Tab. 3. The wave absorber gives the highest value for the slope 1:2.5 of the rubble mound breakwater model.

Tab. 3 Rundown at the mean high water level

Format of Slope	Rundown, R_d (cm)
1:1,5	14.0
1:2	18.5
1:2,5	28.0

The elevation of the crest should be at minimum at which overtopping occurs. This should be based on maximum wave runup [2]. Tab 4 presents the overtopping at the water level at 63 cm with variation of slope of the rubble mound breakwater model that facing the seaward.

Tab. 4 Overtopping at 63 cm of the water elevation

Slope	Overtopping (cm)
1:2	7.6
1:2.5	9.5

The wave transmission coefficient (K_t) is defined as the ratio of the transmitted wave height (H_t) at the leeside to the incident wave height (H_i) at the breakwater seaward, as follows

$$K_t = \frac{H_t}{H_i} \quad (1)$$

The value of K_t indicates the effectiveness of a rubble mound breakwater at submerged condition to attenuate waves [5]. The value of K_t varies between 0 and 1. The value of zero implies that there is no transmission. The value of 1 means no reduction in wave height (there is no barrier in front of the wave). The result of wave transmission coefficient is presented in Tab. 5 at the water level 70 cm (submerged).

Tab. 5 Wave transmission coefficient at the water level 70 cm

Slope	H_t (cm)	H_i (cm)	K_t
1:1.5	7.8	8.5	0.923
1:2.0	8.9	13.9	0.640
1:2.5	9.8	15.4	0.636

Based on the result of wave transmission coefficient, the slope 1:2.5 of the rubble mound breakwater model can reduced the wave height greater than the slope 1:1.5 and 1:2 of the breakwater model, respectively.

The stability of the structure can be observed in the form of displacement armor testing on the breakwater and at toe for the variety of slope and water level variations. Figs. 6, 7, and 8 show the documentation of displacement armor before and after testing for the slope 1:1.5, 1:2, and 1:2.5 of the rubble mound breakwater model, respectively. It can be seen from those figures that the armor units is not displace at the slope 1:2.5 of rubble mound breakwater model compare to the slope 1:1.5 and 1:2.



Fig. 6 Documentation of armor displacement before (left) and after (right) running for the slope 1:1.5 of the rubble mound breakwater model



Fig. 7 Documentation of armor displacement before (left) and after (right) running for the slope 1:2 of the rubble mound breakwater model



Fig. 8 Documentation of armor displacement before (left) and after (right) running for the slope 1:2.5 of the rubble mound breakwater model

5. Conclusions

The function of rubble mound breakwater is to protect the coastal area. Since the rubble mound breakwater need to be in stable condition, the two dimensional physical model of rubble mound breakwater is conducted by using three different slope, i.e., 1:1.5, 1:2, and 1:2.5 that facing the seaward side. The water levels are applied at the mean low water level, the mean high water level, the crest elevation and submerged using the flume with regular wave. The rubble mound breakwater model is designed based on stability of this breakwater using Hudson formula. The armor units of rubble mound breakwater model are tetrapod that is placed randomly facing the seaward. The core is set stable by using geotube. The wave absorber, transmission wave and displacement of armor units give the best result for the slope 1:2.5 of the rubble mound structure model. Further research is needed to conduct for three dimensional of rubble mound breakwater model generating by irregular waves.

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