Two-Dimensional Submerged Rubble-Mound Breakwater Model using Tetrapod at Armor Layer

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Abstract

Coastal erosion occurs at several coastal areas in Indonesia. This coastal erosion is urgently needed to handle by constructing the soft and/or hard structures. The hard structure that help to avoid the coastal erosion is breakwater. The rubble-mound breakwater is usually applied since the material, that is needed, is easy to find in Indonesia and is easy to set up in the chosen location. The stable of rubble-mound breakwater is usually constructed based on the condition of non-submerged structure. The aim of this study is to analyze the stability on two dimensional submerged rubble-mound breakwater model. The two-dimensional of submerged rubble-mound model is carried out in a flume at Balai Pantai, Ministry of Public Works, Buleleng, Bali, Indonesia. The wave simulation is applied using regular wave. The armor layer facing the seaward uses tetrapod that placed randomly. The core layer use two variations, i.e., with and without geotube. The slope of the rubble-mound model facing the seaward is 1:1,5. The submerged condition is set up at water level 70 cm. The measured parameters of this study are the wave height period in front of and behind the breakwater structure. The analysis that can be done is the transmission wave. The placement of geotube at core layer help to maintain the stability of the rubble-mound breakwater. This physical model of submerged rubble-mound breakwater is useful as tool aid before construct the breakwater at the coastal to reduce the structural failure.

Keywords: geotube; rubble-mound breakwater; submerged structure; tetrapod; transmission

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INTRODUCTION

Indonesia is the largest archipelago in the world that cannot avoid the existing problem in the coastal areas such as erosion and/or sedimentation. Coastal erosion could cause huge losses to the destruction of residential and/or infrastructure in the coastal areas [1]. In order to embattle the coastal erosion, the first step that must be done is to find the cause of the erosion. By knowing the cause can then be determined to overcome them, which usually is made of coastal protection or increase the supply of sediment.

Coastal structure used to protect the coast against damage due to attack of waves and currents. One of the coastal structures built in the coastal offshore and roughly parallel to the coastline is breakwater. Rubble mound breakwater is constructed by a pile of stones that at the armour layer made of the large size of stone, concrete blocks, concrete or artificial stone with special shapes such as tetrapods, quadripods, tribars, dolos, and so forth. Type breakwater used is usually determined by the availability of materials at or near the job site, the sea conditions, water depth, and the availability of equipment for the implementation of the work. Stone is one of the main ingredients used to make the breakwater. Availability of stones around the job site should be considered given the required number of very large.

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On the other hand, Indonesia as an archipelago country, does not escape the impact of global warming by the sea level rise which resulted in changes in the coastline due to erosion and/or abrasion. In addition to global warming, the forces of nature such as waves, currents, tides, and construction errors caused major damage to the existing breakwater. In general, construction fault lies in the tilt angle of the structure, a thick layer, and heavy rock, in addition to other factors. This can lead to the collapse of the breakwater. Testing breakwater on the ground will take considerable time and considerable expense. To avoid this, the test is done using a physical model in the laboratory.

Two-Dimensional Submerged Rubble-Mound Breakwater Model using Tetrapod at Armor Layer

The stable of rubble-mound breakwater is usually constructed based on the condition of non-submerged structure. This paper focused to analyze the stability on two dimensional submerged rubble-mound breakwater model and the model carried out in a flume at Balai Pantai, Ministry of Public Works, Buleleng, Bali, Indonesia using regular wave. The armor layer facing the seaward uses tetrapod that placed randomly. The core layer uses two variations, i.e., with and without geotube. The slope of the rubble-mound model facing the seaward is 1:1,5. The submerged condition is set up at water level 70 cm. The measured parameters of this study are the wave height period in front of and behind the breakwater structure. The analysis that can be done is the transmission wave.

RUBBLE MOUND STRUCTURE

A breakwater built as a rubble-mound is constructed by placing material of various sizes layer by layer (or unit by unit) until the desired cross-section shape is achieved. 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].

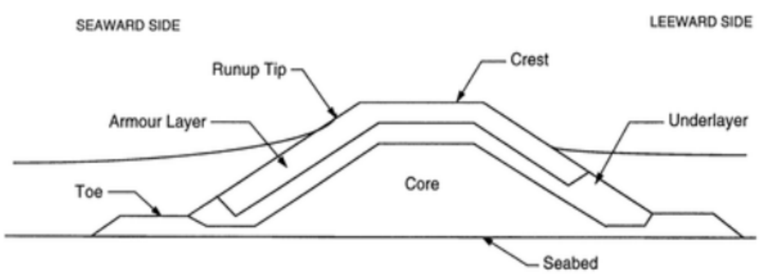

Fig. 1: Cross section of a typical rubble mound breakwater

Generally, the units are not structurally connected, so that the integrity of the rubble-mound depends on features such as the weight of the material, the interlocking nature of the material, and the cross section of the structure. The structure is usually built with material graded from smaller sizes in the core to larger material armoring the face against wave attack [3]. The armor layer may be composed of quarry-stone, if it is available in the required sizes and is economically feasible to use. When these conditions are not met, specially designed concrete units for armoring the face of the rubble-mound have been developed that tend to interlock better than rock when properly placed; hence, it may be possible to use armor units lighter than the required quarry-stone. Over the year numerous geometric shapes have been developed for such armor units, with each shape generally introduced in an attempt to improve on the interlocking characteristics of its predecessors. To mention only a few, various names used for different units are: tribars, tetrapods, quadripods, and dolosse. In this paper, the armor layers use tetrapod that can be seen in Fig. 2.

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Fig. 2: Tetrapod Model

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 integrity of a rubble-mound structure is primarily a function of the stability of the individual armor units that form the seaward (or shoreward) face the structure. Hence, a major design criterion is to determine the minimum weight of units that will yield a prescribed percentage of damage for a given incident wave system; the condition of no damage corresponds to the incipient motion of the armor material [4]. The core layer is set by using or without using geotube. Geotube is a sand material filled geotextile tube made of permeable but soil-tight geotextile.

Wave transmission behind rubble mound breakwaters is caused by wave regeneration due to overtopping and wave penetration through voids in the breakwater. Wave transmission affected by crest elevation, crest width, seaside and lee-side face slopes, rubble size, breakwater porosity, wave height, wave length and water depth. Transmission coefficient is presented by

$$K_r = \frac{H_r}{H_i} \quad (1)$$

where H_r is transmitted wave height and H_i is the incident wave height. 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 to 1. Value of zero implies that there is no transmission. Value of 1 means no reduction in wave height (there is no barrier in front of the wave).

EXPERIMENT SET UP AND PROCEDURE

The experimental researh 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 reguler wave. Three wave probes are installed in the wave flume (Fig. 3).

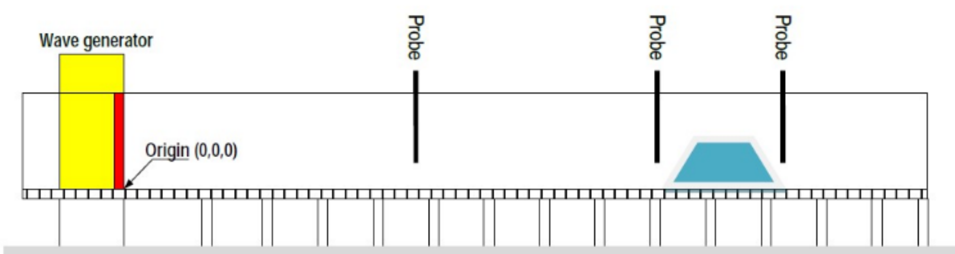

Fig. 3: Side View of the Flume

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The armor units use Tetrapod with the average mass of 280 g, the relative density of 2.054 gr/cm^3, and K_d is 8. The tetrapod is randomly placed at the armor layer. The core layer is set with and without geotube. The slope facing the sea side of the breakwater model is 1:1.5. The wave period is 2 sec. The wave height is 12.42 cm. Fig. 4 and 5 present the side view of the rubble mound breakwater model with the slope 1:1.5 without and with geotube at the core layer, respectively. The rubble mound breakwater model is designed based on stability of rubble mound structure using Hudson formula [6]. The similarity of the rubble mound breakwater model is 1:10.

Fig 4: Side view of rubble mound breakwater model with slope without geotube at core layer

Fig. 5: Side view of rubble mound breakwater model with geotube at core layer

The water levels at the submerged condition is conducted at water levels 70 cm.

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 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. The value of K_t indicates the effectiveness of a rubble mound breakwater

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at submerged condition to attenuate waves [5]. The result of wave transmission coefficient is presented in Tab. 1 at the water level 70 cm (submerged).

Table. 1 Wave transmission coefficient

Core Layer	H_t (cm)	H_i (cm)	K_t
Without Geotube	2.2	6.4	0.344
With Geotube	8.5	12.5	0.680

Based on the result of wave transmission coeficient, the core layer using Geotube of the rubble mound breakwater model can reduced the wave height more greater than the core layer without using Geotube of the rubble mound breakwater model. The stability of the structure can be observed in the form of displacement armor testing on the breakwater. Figs. 6 and 7 show the documentation of displacement armor for the core layer without Geotube and with Geotube of the rubble mound breakwater model, respectively. It can be seen from those figures that the armor units is not displace at the core layer using Geotube of rubble mound breakwater model compare to the core layer without Geotube.

Fig. 6: Documentation of armor displacement after running for the core layer without using Geotube of the rubble mound breakwater model

(a) (b)

Fig. 7: Documentation of armor displacement before (a) and after (b) running for the core layer using Geotube of the rubble mound breakwater model

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CONCLUSIONS

The function of rubble mound breakwater is to protect the coastal area. The rubble mound breakwater model is designed based on stability of this breakwater using Hudson formula. Since the rubble mound breakwater need to be in stable condition, the two dimensional physical model of rubble mound breakwater is conducted using the slope, i.e., 1:1.5 that facing the seaward side. The water levels are applied at submerged condition using the flume with reguler wave. The armor units of rubble mound breakwater model are tetrapod that is placed randomly facing the seaward. The core is set with and without using geotube. The transmission wave and displacement of armor units give the best result for the core layer using Geotube of the rubble mound structure model. The placement of geotube at core layer help to maintain the stability of the rubble-mound breakwater. This physical model of submerged rubble-mound breakwater is useful as tool aid before construct the breakwater at the coastal to reduce the structural failure. Further research is needed to conduct for three dimensional of rubble mound breakwater model.

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