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Wave-Induced Pressure Distribution on Placed Perforated Revetment Block

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Abstract

In order to evaluate the stability of revetment block against wave attack, the information about hydrostatic pressure distribution induced by the wave is needed. In this paper, a simple mathematical model is developed to calculate the pressure distribution on revetment, which taking the effect of flow in filter layer and the perforated surface of revetment block into account. Physical test were done to observe the flow in filter and the coefficient discharge of perforated surface. The effect of filter and perforated surface latter on will called as filter-pore parameter. Model investigation were also performed on various filter under the loading condition which represent the wave loading. The result of this model investigation were compared to the mathematical model, and shows a great agreement between both of them. The result from both simulation shows that the filter-pore parameter has a great influence on the hydrostatic-pressure that act on the revetment block.

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Keywords: *Revetment block, wave, pressure distribution, perforated block, filter layer;*

1. Introduction

In order to deal with the coastal erosion problem, a wide range of engineering solutions have been applied, with special focus on shore protection structures. One of them is using revetment structure. Revetments arise as an equally effective but less aggressive intervention technique, since it reduced the negative effects (i.e., high wave reflection, excessive turbulences) [1]. The revetment structure consist of the cover layer and filter layer. The cover layer of a revetment may be permeable or impermeable and rigid or flexible depending on the materials used for its construction. The filter is a transitional layer made up of geotextile, granular material (e.g. gravel, crushed stone) or a combination of both [2].

Concrete block has been used as one of the cover layer material during last decade with a large variety such as the shape, the placement system, etc. Within all the variety, a modification to make the surface of block revetment more permeable (with the gap or with porous) became an attractive technique in the purpose of increasing the stability of revetment block. The existence of perforated surface increase the porosity and the roughness of revetment block, which lead to partial dissipation on wave energy, and decreasing the risk of excessive build-up hydrostatic uplift pressure generated by wave action [3].

Wave action on revetment is a complicated process and resulted of various external loading on the revetment itself which is difficult to identify. However the hydraulic loading at least depends on a number of variables i.e. wave heights and periods, angle of wave attack, type and location on breaking wave, grouping of waves, wave run up and run down, tidal level, and current.

Bezuijen et al. [4] explained that the revetment comprises blocks placed on a filter layer of gravel (see Figure 1), may be subjected to a certain types of hydraulic loads. The most important load in analyzing the stability of revetment cover layer is the quasi-static pressure forces on the cover layer caused by the difference between the pore pressure in filter layer and the wave pressures on the revetment.

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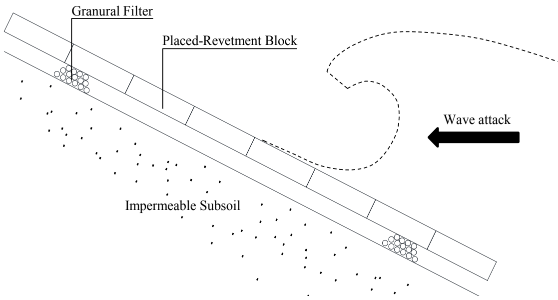

Fig. 1. Placed revetment block on filter consist of granular layer

The most critical upward pressure that may cause a failure in cover layer of a revetment, occurs at the time when the wave rundown reach maximum value [5]. In this time, there will be an incoming wave that a moment latter will cause a wave impact. Just before the impact there is amount of water giving a high pressure under the point of maximum run-down. Above the run-down point the surface of the revetment almost dry, hence the downward pressure that act on revetment cover is very low. The high pressure front will lead to an upward flow in the run-down region. This flow will meet the downward flow in run-up region. The result is an outward flow and uplift pressure near the point of maximum run-down.

This perception of loads on a series of block revetment that form the basis of this research. Hence, the flow mechanism in filter layer, as well as the characteristic of revetment block are the main focused parameter In order to analysis the quasi-static pressure on revetment block.

In this paper, a simple mathematical model is developed to calculate the pressure distribution on revetment, which taking the effect of flow in filter layer and the perforated surface of revetment block into account. Model investigations were conducted to observe the pressure distribution by simulating the flow in filter which is represent the result of wave action on the revetment. In this way, how perforated surface of revetment block and size of filter material effect the pressure are studied.

2. Flow Through the Porous Media

Burcharth and Andersen [6], by using Navier-Stokes equation which principally describe the kinematic and dynamic conditions for a fluid element in steady closed conduit flow in porous media, derived the pressure gradient equation of flow through porous media from that can be written as follow,

$$I_i = \alpha \frac{\upsilon}{g} \frac{U}{D^2} + \beta \frac{1}{g} \frac{U^2}{D} \tag{1}$$

This identical to Forchheimer equation ($I_i = A'U + B'U^2$), where the quadratic term represent the dependence of inertial forces (inertia term). If in Eq. (1) the characteristic velocity *U* is subtitued by *V/n*, where *V* is the discharge velocity and n is the porosity, while the characteristic length, *D* is substituted by a hydraulic radius R, defined as the ratio of pore volume over pore surface area, it can be obtained,

$$I_i = \alpha \left(\frac{1-n}{n} \right)^2 \frac{\upsilon}{g} \frac{V}{d^2} + \beta \frac{1-n}{n^3} \frac{V^2}{gd} \tag{2}$$

With $R = n / I - nd / 6$ α depends on *Re*, the gradation and the grain shape, and *β* depends on the same parameters plus the relative roughness of the grains.

For a very low velocity flow, the inertia term can be neglected, and the viscous term are more dominated. This condition usually describe as a laminar regime. Thus the solution can be written,

$$I_i = \alpha \left(\frac{1-n}{n} \right)^2 \frac{\upsilon}{g} \frac{V}{d^2} = AU \tag{3}$$

Which is well-known as the Darcy equation. On the other hand, for higher flow velocities, the role of inertial forces overcomes the viscous one and after a transition regime, it leads to what is called turbulent flow regime, which is totally dominated by inertial forces [7]. Therefore the equation can be obtained in the form,

$$I_i = \beta \frac{1-n}{n^3} \frac{V^2}{gd} = BU^2 \tag{4}$$