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Developing a Stability Formula for Breakwater-An Overview

^{1,2}Nur Aini Mohd Arish, ²Othman A. Karim, ²Wan Hanna Melini Wan Mohtar¹Faculty of Civil and Environmental Engineering, Universiti Tun Hussein Onn Malaysia²Department of Civil and Structural Engineering, Faculty of Engineering and Built Environment, Universiti Kebangsaan Malaysia

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ABSTRACT

Armour layer stability is very important in designing a breakwater. The paper presents an overview of the past and current state for developing new formula of stability for breakwater. In developing stability formula, primary variables affecting armour stability such as nominal diameter, relative mass density, height of significant wave, wave period, slope angle, damage level, permeability, porosity, spectrum of shape, number of waves, wave incidence angle are some of the major concerns to many researchers. This paper will also highlights the needs of permeability and wave incidence angle to be included in the stability formula since these parameters sometimes were neglected.

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INTRODUCTION

The conventional rubble-mound breakwater consists of a core of finer material covered by big blocks, which is called as an armour layer. The armour layers are important as to prevent the finer material of a breakwater from eroding and washed away and to minimum the wave attack (Kamali, B. and R. Hashim, 2009).

Several treatments for biodiesel wastewater are shown in Table 2. Most of the treatments were done in order to find the better treatment in terms of performance, cost and simplicity. The authors are going to investigate and evaluate the performance of integrated system; coagulation-biological aerated filter (CBAF) system to be used as biodiesel wastewater treatment.

Breakwater structures consisting of armour layer, filter layer and core are referred to as multilayer structures (CEM 2006). The armour layer of a rubble mound breakwater can be built with a large variation of armour units and nowadays besides quarry stone or rock, various types of concrete armour units are used such as cubes, Xbloc, dollose, tetrapode and Accropode (Van Broekhoven, P.J.M., 2011). The design of armour units protecting coastal structures against waves is based on hydraulic model tests and empirical formulas (SPM 1984).

Although many formulas were derived for over the past years but somehow certain important parameters such as permeability and wave incidence angle are not included in the formulas. For example, one of the most applied formulas, the Hudson (Sulisz, W., 1995) formula does not include these two parameters. One of the reason that permeability is not taken into consideration is the analysis of the effect of permeability on the rubble mound stability will be time consuming and expensive since there are many others parameters involved in the analysis itself (Wolters, G. and M.R.A. van Gent, 2010). Researches by (Yu, Y.X., 2002; Galland, J.C., 1994; Van der Meer, J.W., 1988) show that wave incidence angle does give significant impact towards the stability of armour layer of breakwater. This paper will look into several formulas that have been developed by some previous researchers and also to see the important of permeability and wave incidence angle on the stability of breakwater since these parameters sometimes were neglected in developing the stability formulas.

Armour Layer Stability:

The empirical formula or stability formula evaluates the minimum required weight of armour that is needed to resist the maximum attack of wave forces allowing an acceptable level of damage. A qualitative stability ratio can be expressed as the drag force plus the lift force divided by the gravity force (CEM 2006):

$$\frac{F_D + F_L}{F_G} \approx \frac{\rho_w D_n^2 v^2}{g(\rho_a - \rho_w) D_n^3} = \frac{v^2}{g \Delta D_n} \quad (1)$$

Corresponding Author: Nur Aini Mohd Arish, Faculty of Civil and Environmental Engineering, Universiti Tun Hussein Onn Malaysia.
Ph: +6019-3803445, E-mail: nuraini@uthm.edu.my

where D_n = nominal diameter; ρ_s and ρ_w = the mass densities of armour units and water; and v is a flow velocity. For a breaking wave height of H , the fluid velocity can be stated as $v = (gH)^{1/2}$ and finally the stability number N_s can be obtained as follow:

$$N_s = \frac{v^2}{g\Delta D_n} = \frac{H}{\Delta D_n} \quad (2)$$

A lot of researches have been performed on the stability of rubble mound breakwaters and many empirical formulas have been developed to predict the stability of armour layer thus indicating the importance of this area of study in coastal engineering. One of the most applied stability formula is the Hudson formula. Hudson (Sulisz, W., 1995) produced a stability formula for estimating the required weight of an individual armour unit in the outer layer of rubble mound breakwater. The formula is expressed by

$$W = \frac{\gamma_s H^3}{K_D \left(\frac{\gamma_s}{\gamma_w} - 1 \right)^3 \cot \alpha} \text{ or } \frac{H}{\Delta D_n} = (K_D \cot \alpha)^{1/3} \quad (3)$$

where W = weight of an armour unit; H = characteristic wave height; γ_s and γ_w = specific weight of armour unit and water; α = slope angle and K_D = empirical stability coefficient. Although this formula is widely used for the design of armour layers but the users found that there are a lot of shortcomings in it. It does neglect some main parameters such as wave period, permeability of the structure, randomness of waves, damage level and certain confusion still surrounds the value of K_D (Hedar, P.A., 1986; Koev, K.N., 1992). This K_D may interpret all the factors that influenced the stability but there is no clear explanation what are those factors and how does they affect the stability (Kamali, B. and R. Hashim, 2009).

The stability formula of Van der Meer (1988) takes much more parameters into account that include wave height, wave period, damage level, number of waves, slope angle, permeability of structure and relative mass density. But still this formula neglecting the wave incidence angle influence. The formula is given according to the wave characteristics:

for plunging (breaking) waves:

$$\frac{H_s}{\Delta D_{n50}} = 6.2 P^{0.18} \left(\frac{S}{\sqrt{N}} \right)^{0.2} \xi_m^{-0.5} \quad (4)$$

for surging (non-breaking) waves:

$$\frac{H_s}{\Delta D_{n50}} = 1.0 P^{-0.13} \left(\frac{S}{\sqrt{N}} \right)^{0.2} \sqrt{\cot \alpha} \xi_m^P \quad (5)$$

where H_s = significant wave height; $\Delta = \rho_r/\rho_w - 1$; D_{n50} = nominal diameter; S = damage level; P = permeability factor; N = number of waves; α = seaward slope angle of the structure and ξ_m = Iribarren parameter. Iribarren parameter or surf similarity parameter is the relation between the wave steepness and structure slope as in the following form

$$\xi_m = \frac{\tan \alpha}{\sqrt{2\pi H_s / g T_m^2}} \quad (6)$$

Hedar (1986) developed an improved formula for armour stability that includes the influence of wave climate, angle of repose and slope angle, density of block material and the fluid, and permeability of the under layers. Koev (1992) derived a formula from a statistical analysis of 21 formulas for determining the stone weight in the armour layer of breakwater. The formula is almost similar to Hudson except that it includes wave steepness (H/L). The formula is valid for wave steepness varying between 0.04 and slopes $\cot \alpha$ between 1.1 and 20. Yu (2002) produced a formula that is modified from Hudson. The modified formula considers the effect of wave obliquity and multi directionality on the armour unit stability. Yu et al. introduced the stability coefficient of armour unit under the attack of oblique waves as the following equation

$$K_{D,\theta_0} = K_s K_D \cos^{-m} \theta_0 \quad (7)$$

where K_s = directional spreading coefficient; K_D = normal stability coefficient; m = index; θ_0 = wave incidence angle. Suh and Kang (2012) introduced a stability formula for tetrapods armouring a rubble mound breakwater

based on hydraulic model test results. Their formula considers the influence of wave period, storm duration, damage level and slope angle. Three different slopes of structure were tested, $\cot \theta = 1.33, 1.5$ and 2.0 . The derivation of this formula was closely according to the procedure described in Van der Meer (1987). The stability formula is proposed as

$$\frac{H_s}{\Delta D_n} = \max \left[\left(9.2 \frac{N_0^{0.5}}{N^{0.25}} + 3.25 \right) \xi_z^{-0.4}, \left(5.0 \frac{N_0^{0.5}}{N^{0.25}} + 0.85 \right) (\cot \theta)^{0.45} \xi_z^{0.4} \right] \quad (8)$$

where N_0 = damage level, N = number of waves, ξ_z = Irribarren number and θ = slope angle. Each term in the braces (Equation 8) represents the plunging and surging waves. The equation is basically the same as those of Van der Meer (1988) except that a slope angle variable is included in the surging wave formula. The formula was applicable to breakwaters with various slope angles and also can be applied for low crested breakwaters.

Influence of Permeability and Wave Incidence Angle on Stability of Breakwater:

a) Permeability:

The effect of permeability on the stability of rubble mounds has been an interest to coastal engineering researchers for many years. As early as in the 1950s and 1960s, several laboratory experiments were done to analyse the influence of permeability on the stability of rubble mound breakwater. Several confusing conclusions were derived as permeability influences were neglected in the analysis of research. The concept of the permeability of a structure is that as the permeability increases it dissipates more energy hence less weight for stability of the armour layer is needed (Heijj, J.E.J., 2001; Coastal Engineering Manual (CEM), 2006). When permeability of the armour layer is increased, the flow at the surface of the armour layer will reduced as a part of the wave volume flows in the armour layer.

Van der Meer (1988) proposed a rock-slope stability formula based on a large number of irregular-wave experiments and the stability formula depends on a number of structural and hydraulic parameters. Van de Meer concluded that the stability of armour layers is strongly influenced by the composition of a structure and thus implemented the influence of the composition in a permeability coefficient P . Three different types of composition were tested; a homogeneous structure, a structure with an impermeable core and a structure with a permeable core. For the three tested composition a different value of P could be fitted, impermeable structure with $P = 0.1$, permeable structures with $P = 0.5$ and for homogeneous structures $P = 0.6$. The permeability factor or the term *notional permeability* is based on curve fitting of the test result of Van der Meer (1988) and therefore the permeability factor has no physical base [16,2]. This permeability coefficient was introduced to ensure that permeability is taken into account into the stability formula.

As an extension study from Van der Meer (1988), a research was done by de Heij (2001) to study whether physical background can be given to the influence of structural permeability on armour layer stability. Structures were modelled with different permeability and the velocities on the slope were calculated for different hydraulic conditions. A mathematical model ODIFLOCS (One dimensional flow on and in coastal structures) was used in this study to calculates depth average velocities on the slope. The stability relation has been computed with the use of the $U_{2\%}$ or average of the highest 2% of the run up or run down velocity. It is found that the influence of permeability on the stability of the structure is depending on the slope angle and wave steepness. Although many researches show that permeability does give significant influence towards the stability, still formulas that were introduced by Hudson not include the parameter in their formulas.

b) Wave incidence angle:

As waves usually attack breakwater obliquely there is a need to investigate the performance of breakwater stability under oblique waves. The influence of wave obliquity on the stability of coastal structures needs to investigate since most scale model tests are mainly conducted in wave flumes when defining guidance for the design of breakwaters. An intensive study have been done by several researchers, Van de Keeke to see the effect of wave obliquity on coastal structures stability.

Galland (1994) performed a series of model tests to quantify the effect of long crested, oblique waves on the stability of rubble mound breakwaters. Four types of armour units (quarry stone, Antifer cube, tetrapod and Accropode) with six angles of wave attack ($0^\circ, 15^\circ, 30^\circ, 45^\circ, 60^\circ$ and 75°) were used. The results show that some trends can be seen which indicate an increase in stability with increasing angle of wave incidence. From figure 1(a) and 1(b), it is found that the armour stability ($H_s/\Delta D_n$) is increasing with increasing of the wave incidence or wave obliquity and the initiation of damage is delayed under oblique waves. But it also can be seen that once the damage initiated, it increases faster under oblique waves than under normal waves. Only a few researchers have included the influence of wave incidence angle in their formula such as Wolter and van Gent (2010).

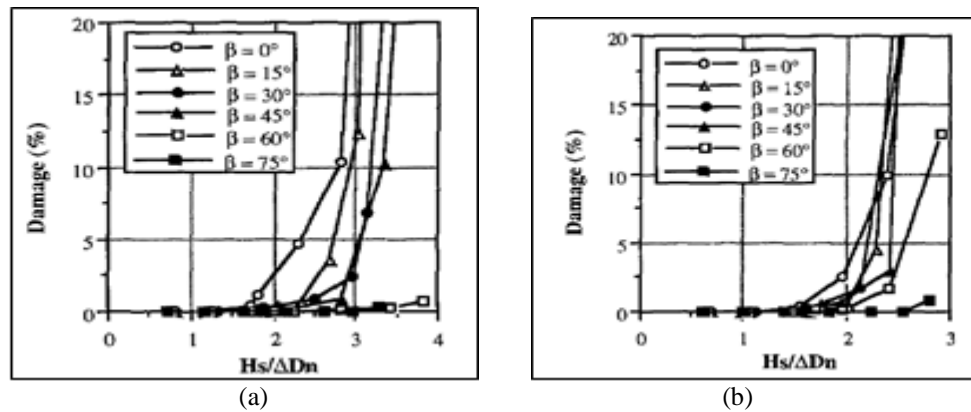


Fig. 1: Armour stability of (a) Antifer cube (b) tetrapod.

Further researches should be done to improve the existing stability formula. The new develop formula should include the permeability and wave incidence angle influences beside other main parameters as these factors shown clearly significant impact towards the stability of armour layer for breakwater.

Conclusion:

Many stability formulas have been developed but there are still inadequacies of present design formulas because almost all of the formulas are still neglecting a few main parameters that influence the stability of a breakwater. This paper would give a better idea of understanding the importance of the influence of wave incidence angle towards armour layers and also the needs of more research to understand comprehensively the permeability influence in more physical aspects since the permeability has large influence on the stability. Hence, by taking in to account all those parameters, a better and reliable formula can be proposed which an experimental work is currently underway.

REFERENCES

- Coastal Engineering Manual (CEM), 2006. Engineer Manual. U.S. Army Engineer Waterways Experiment Station, U.S. Government Printing Office, Washington, DC. (6 volumes).
- Galland, J. C., 1994. Rubble mound breakwater stability under oblique waves: An experimental study, Proc. 24th ICCE, Kobe Japan, pp: 1061-1074.
- Hedar, P.A., 1986. Armor layer stability of rubble-mound breakwaters. J. of Waterway, Port, Coastal, and Ocean Eng., 112(3): 343-350.
- Heijj, J.E.J., 2001. The influence of structural permeability on armour layer stability of rubble mound breakwater. Msc. Thesis, Delft University of Technology, Delft, The Netherlands.
- Jumelet, H.D., 2011. The influence of core permeability on armour layer stability, A theoretical research to give notional permeability coefficient P a more physical basis. Msc. Thesis, Delft University of Technology, Delft, The Netherlands.
- Kamali, B. and R. Hashim, 2009. Recent advances in stability formulae and damage description of breakwater armour layer. Australian Journal of Basic and Applied Sciences, 3(3): 2717-2827.
- Kik, R., 2011. Notional Permeability of breakwaters, Experimental research on the permeability factor P . Msc. Thesis, Delft University of Technology, Delft, The Netherlands.
- Koev, K.N., 1992. Statistical analysis of formulae for breakwater armor layer design. J. of Waterway, Port, Coastal and Ocean Eng., 118(2): 213-219.
- Suh, K.D., J.S. Park, 2012. Stability formula for tetrapods. J. of Waterway, Port, Coastal, and Ocean Eng., 138(3): 261-266.
- Sulisz, W., 1995. Effect of permeability on stability of rubble bases. J. of Waterway, Port, Coastal, and Ocean Eng., 121(3): 162-166.
- U.S. Army Coastal Engineering Research Center, Shore Protection Manual, Vol. II, U.S. Government Printing Office, Washington, D.C., 1984.
- Van Broekhoven, P.J.M., 2011. The influence of armour layer and core permeability on the wave run-up. Msc. Thesis, Delft University of Technology, Delft, The Netherlands.
- Van der Meer, J.W., 1987. Stability of breakwater armour layers-Design formulae. Coastal Engineering, 11: 219-239.
- Van der Meer, J.W., 1988. Stability of cubes, tetrapods and accropode. Thomas Telford Limited, London, pp: 59-68.

Wolters, G. and M.R.A. van Gent, 2010. Oblique wave attack on cube and rock armoured rubble mound breakwater. Proc. 32th ICCE, Shanghai China.

Yu, Y.X., S.X. Liu, C.H. Zhu, 2002. Stability of armour units on rubble mound breakwater under multi-directional waves, Coastal Engineering Journal, 44(2): 179-201.