DESIGN OF RUBBLE-MOUND BREAKWATER: INTRODUCING A FORMULA FOR THE PERMEABILITY

A. Jafari[1] A. Etemad-Shahidi[2]

INTRODUCTION

Determining the optimum weight of the armour blocks is the most important issue in design of breakwaters. Existing empirical formula, such as those of Hudson (1958) and Van der Meer (1988), depict considerable scatter between the predicted stability number and the measurements. This scatter imposes higher safety factor and increases the construction costs. Numerous researchers put efforts in this issue to increase the accuracy of the prediction by using different m models. However, the proper definition for the permeability parameter of the rubble-mound coastal structures is yet missing. In this paper, a semi-empirical formula for the permeability parameter is introduced and improvement in design of the rubble-mound breakwater is presented.

EQUATION OVERVIEW

Van der Meer (1988), hereafter referred to as VdM, developed the following empirical formula to predict the stability number, $N_s=H/\Delta D_{50}$, of of rubble-mound breakwater under plunging and surging breaker type,

$$N_s = 6.2S^{0.2} P^{0.18} N_w^{-0.1} \xi_m^{-0.5} \quad \text{if } (\xi_m < \xi_{mc}) \;\&\; \cot\alpha \le 4 \qquad (1)$$

$$N_s = S^{0.2} P^{-0.13} N_w^{-0.1} \xi_m^{P} \cot\alpha^{0.5} \quad \text{if } (\xi_m \ge \xi_{mc}) \;\&\; \cot\alpha \ge 4 \qquad (2)$$

where N_w is the number of wave attack, P is the nominal permeability of breakwater (Fig. 1), ξ_m is the surf similarity parameter, cot α is slope angle, *S* is the damage level and N_s is the stability number. The permeability parameter in equations. (1) and (2) depends on the permeability of core layer. VdM suggested values of *P* range from 0.1 for a relatively impermeable core to 0.6 for homogenous rock structures (Fig. 1).

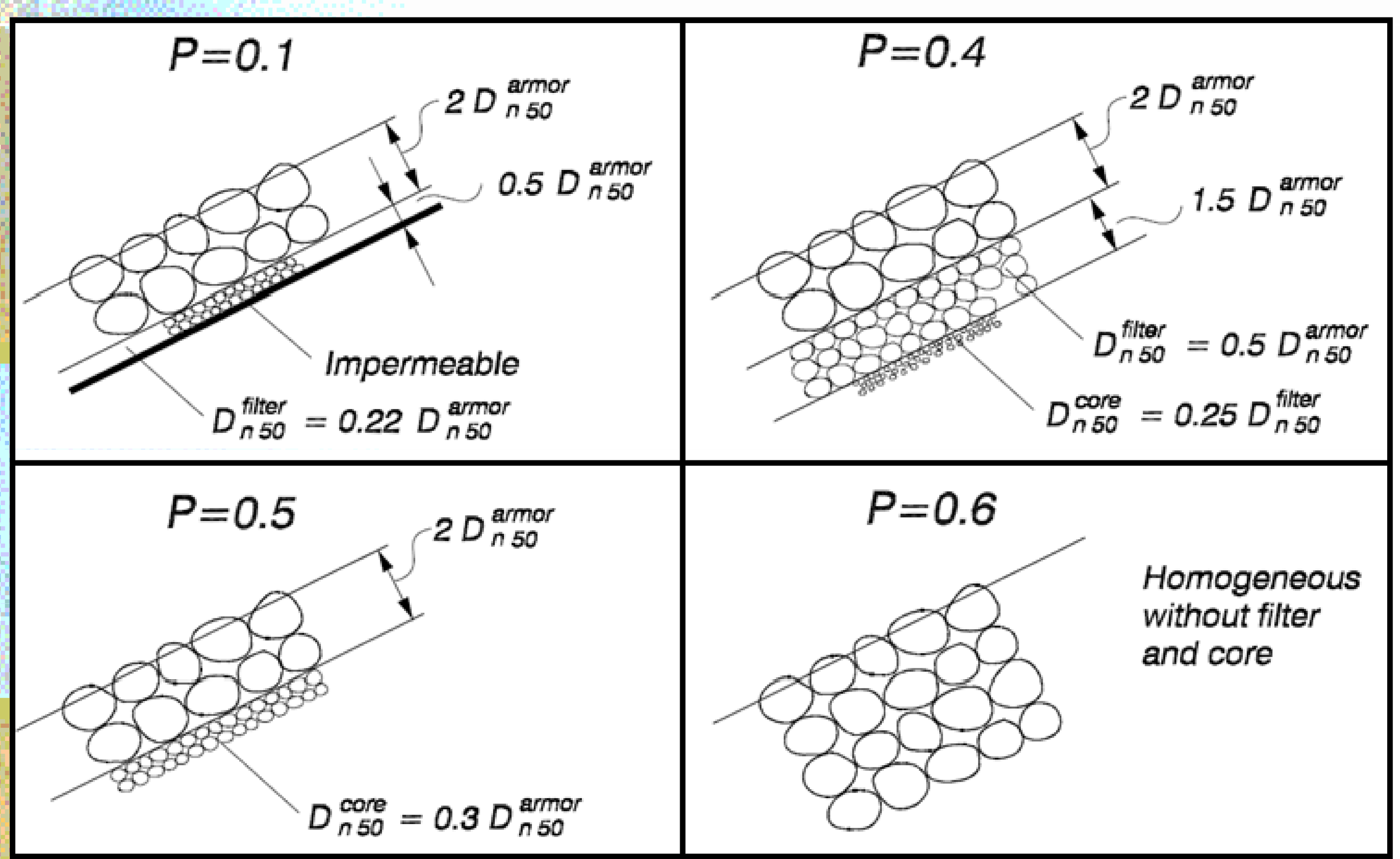

Fig. 1: Notational Permeability Coefficient s (Van der Meer 1988)

Vidal et al. (2006), hereafter referred to as VML, showed that H_{50} is a more appropriate wave parameter in calculating the stability number. H_{50} is the average wave height of the 50 highest waves reaching a rubble-mound breakwater in its useful life. They showed that there is no need to consider the number of waves provided that H_{50} is used instead of H_s.

Using H_{50} , Etemad-Shahidi and Bali (2012), hereafter referred to as EB12, used H_{50} instead of H_s to introduce a simple formula for the stability of rock armours,

$$N_{50} = 4.24S^{0.17} P^{0.18} \xi_m^{-0.4} \qquad (3)$$

This formula was developed using both VdM and VML laboratory measurements.

Fig 2 present the comparison of measured and predicted stability number for four different approaches, which are VdM, VML, EB12, and Etemad-Shahidi and Bonakdar (2009), hereafter referred to as EB09. In all of these formulae the nominal definition of P (Fig. 1) has been used.

Also, four statistical error measures were used to evaluate the performance of each of the aforementioned models which are scatter index (*SI*), correlation coefficient(*CC*), and index of agreement (I_a) (c.f. Etemad-Shahidi, A. and Bali, M., 2012). The following table (Table 1) shows the accuracy metrics of different formulas for the prediction of stability number.

Table 1: Accuracy metrics of different formulas for the prediction of N_s (Bali & Etemad-Shahidi, 2011)

Formulas	*Bias*	*SI*	*CC*	I_a
Van der Meer (1988)	-0.11	0.18	0.73	0.8
Vidal et al. (2006),	0.1	0.17	0.723	0.81
Etemad-Shahidi and Bonakdar (2009)	-0.13	0.17	0.763	0.83
Etemad-Shahidi and Bali (2012)	0.04	0.12	0.86	0.93

1- Natural Hazard Unit, The City of Gold Coast, ajafari@goldcoast.qld.gov.au
2- Griffith School of Engineering, Griffith University, a.etemadshahidi@griffith.edu.au

The results of EB12's formula indicates improvement in scatter index (SI), correlation coefficient(CC), and index of agreement (Ia) of stability number.

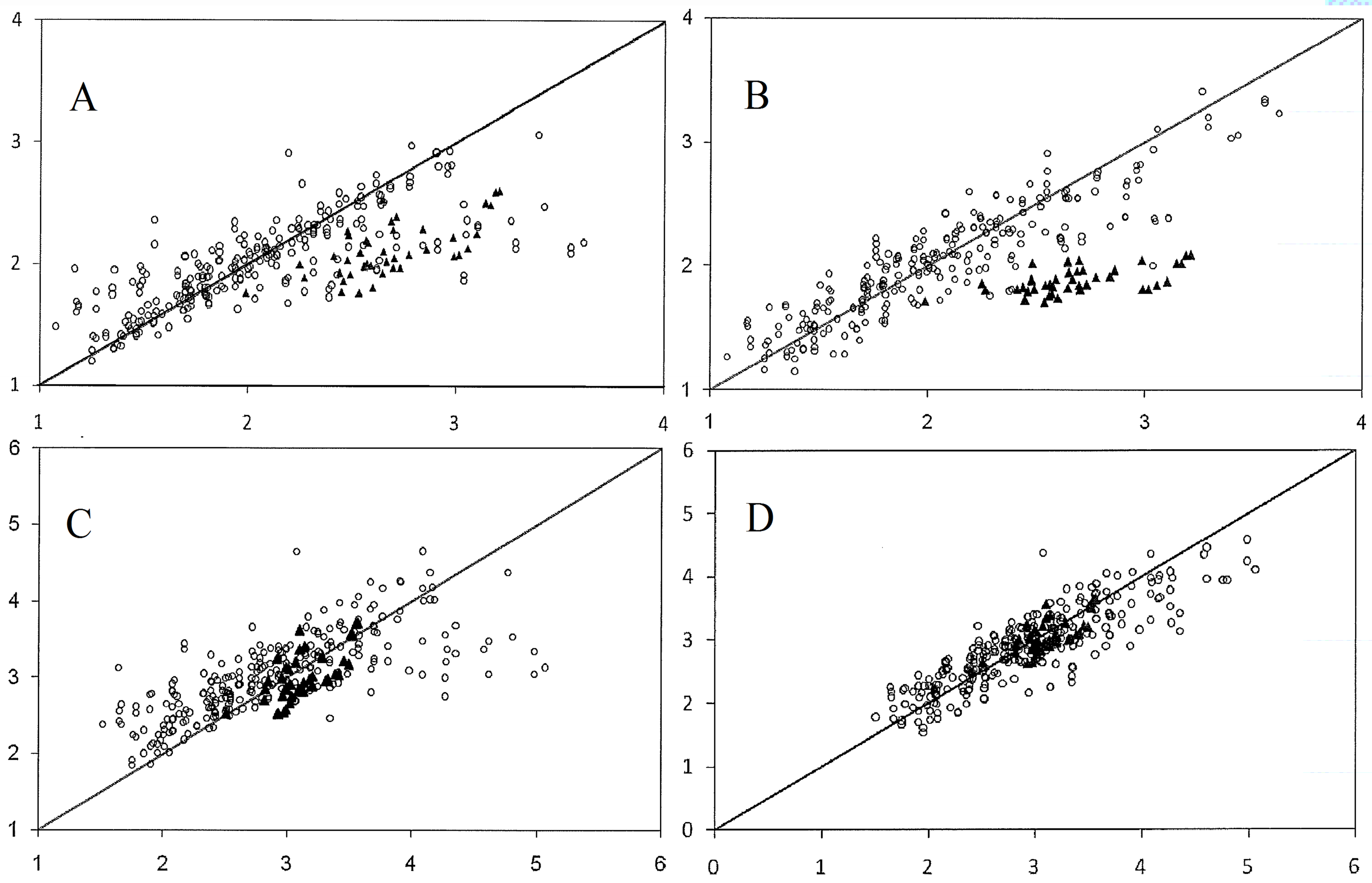

Fig. 2: Comparison of measured and prediction of N_s, (A)VdM, (B) EB09, (C) VML, (D) EB12; (○) VdM data, (▲) VML data

METHODOLOGY & RESULT

In this research, the data sets of VdM and VML were used to quantify the permeability of the breakwater based on the non-dimensional governing parameter. First step in this regard was to identify the governing parameters. Therefore, different parameters were examined through extensive regression analysis. Results showed that the most effective parameters in evaluating the rubble-mound breakwater permeability were the core diameter (D_c), armour diameter (D_A), and the wave period. Figure 2 depicts the relationship between non-dimensional governing parameter and the computed values of P based on equation (3) .

In order quantify the permeability, equation (3) was rearranged to extract $P^{0.18}$ based on other parameters. Then results was used to extract a relation for permeability based on non-dimensional wave period $\sqrt{gT_m^2/D_A}$ and the ratio between core diameter and armour diameter (D_c/D_A). To derive the relationship, different data mining approached were employed and the following formula was derived for the permeability number.

$$P = 0.055 \times \sqrt{\frac{gT_m^2}{D_A}} \times \left(\frac{D_c}{D_A}\right)^{0.141} \qquad (4)$$

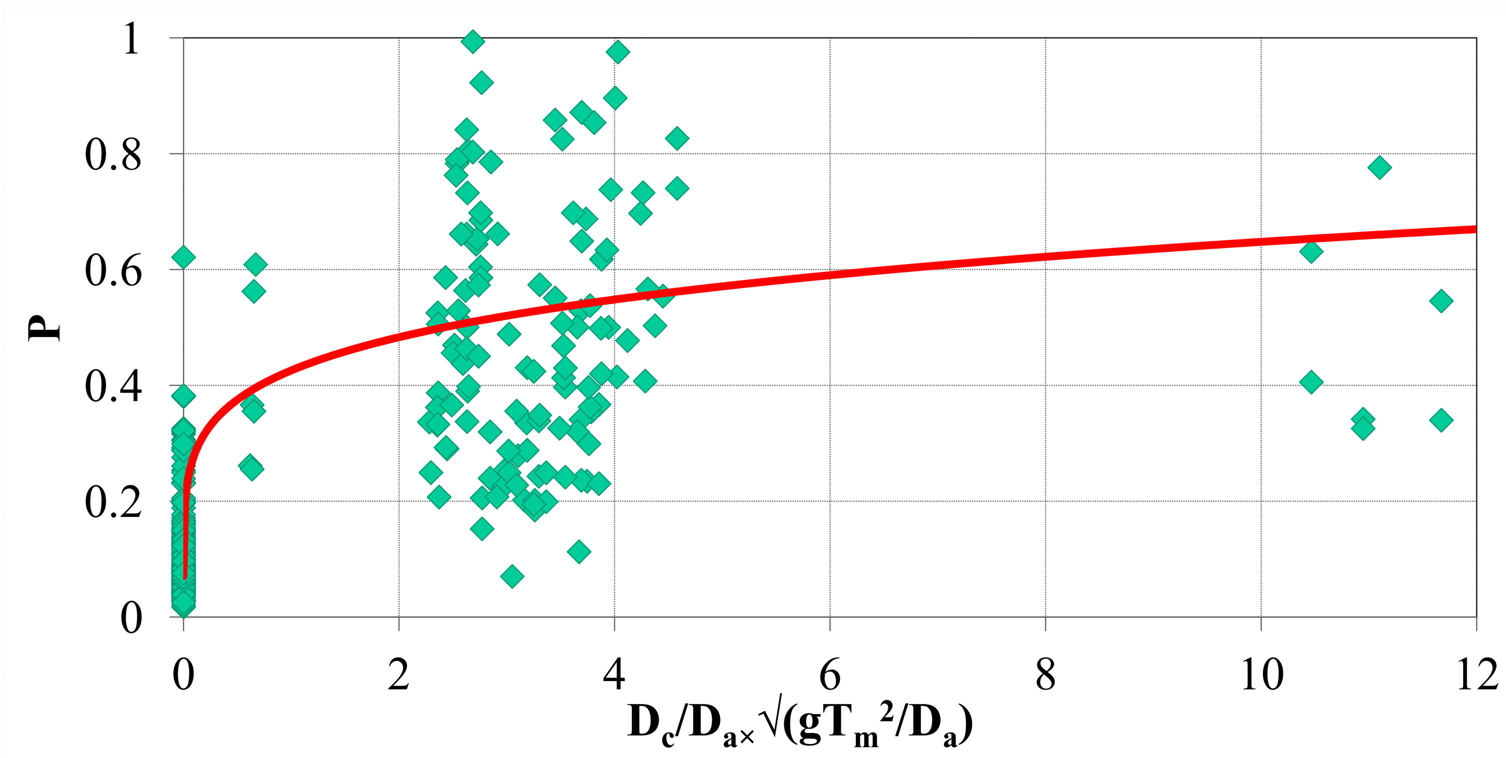

Fig. 2: Relation between non-dimensional governing parameter and the computed values of P based on rearranging the equation (3)

REFERENCES

Bali, M. and Etemad-Shahidi, A. (2011). Study of wave height parameter effect in design of rubble-mound breakwater. 4th National Offshore Industries Conference, Sharif University, Tehran, Iran.

Etemad-Shahidi, A. and Bali, M., (2012). *Stability of rubble-mound breakwater using H_{50} wave height parameter.* Coastal Engineering, 59(1): 38-45.

Etemad-Shahidi, A. and Bonakdar, L., (2009). Design of rubble-mound breakwaters using M5′ machine learning method. Applied Ocean Research, 31(3): 197-201.

Hudson, R., (1958). *Design of Quarry-Stone Cover Layers for Rubble-Mound Breakwaters*, DTIC Document.

Van der Meer, J.W., (1988). *Rock slopes and gravel beaches under wave attack.*

Vidal, C., Medina, R. and Lomónaco, P., (2006). *Wave height parameter for damage description of rubble-mound breakwaters.* Coastal Engineering, 53(9): 711-722.