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

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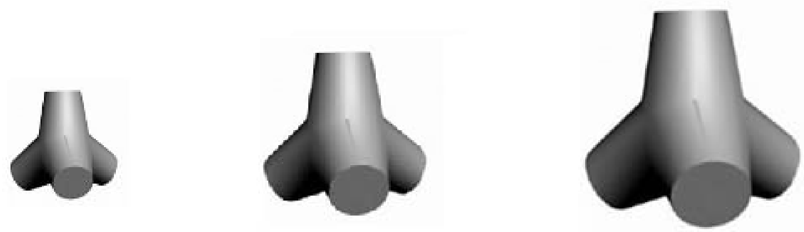
SIGNIFICANCE

Determining the optimum weight of the armour blocks is the most important issue in design of breakwaters.



Hudson (1958)

$$\frac{H_s}{\Delta D_{n50}} = \frac{\sqrt[3]{K_D \cot\alpha}}{1.27}$$

Van der Meer (1988)

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

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

EQUATION OVERVIEW

Van der Meer (1988)

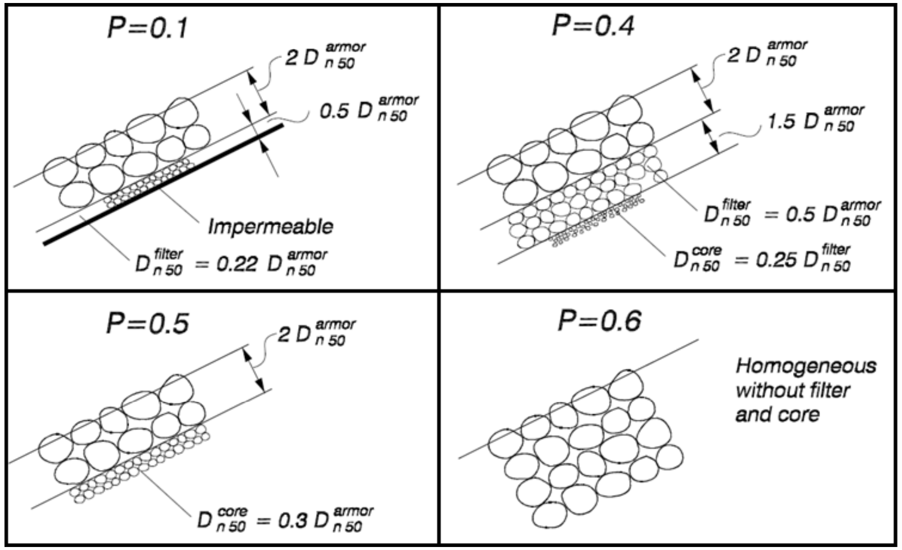
Plunging

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

Surging

$$N_s = S^{0.2} P^{-0.13} N_w^{-0.1} \xi_m^{p} \cot\alpha^{0.5} \quad \text{if } (\xi_m \geq \xi_{mc}) \,\&\, \cot\alpha \geq 4$$

$$N_s = \frac{H_s}{\Delta D_{n50}}$$



- N_s is the stability number
- S is the damage level
- N_w is the number of wave attack
- ξ_m is the surf similarity parameter
- cotα is the slope angle
- P is the nominal permeability of breakwater

EQUATION OVERVIEW

- Vidal et al. (2006), showed that H_{50} is a more appropriate wave parameter in calculating the stability number.
- No need to consider number of waves provided that H_{50} is used instead of H_s

$$N_{50} = 4.44 S^{0.2} P^{0.18} \xi_m^{-0.5} \quad \text{If } (\xi_m < \xi_{mc}) \text{ and } \cot\alpha \le 4$$

$$N_{50} = 0.716 S^{0.2} P^{-0.13} \xi_m^{P} \sqrt{\cot\alpha} \quad \text{If } (\xi_m \ge \xi_{mc}) \text{ and } \cot\alpha \ge 4$$

$$N_{50} = \frac{H_{50}}{\Delta D_{n50}}$$

- H_{50} is the average wave height of the 50 highest waves reaching a rubble-mound breakwater in its useful life,
- D_{n50} is the nominal diameter of stone,
- $\Delta=\rho_s/\rho_w-1$ is the relative density of stone

EQUATION OVERVIEW

- Etemad-Shahidi and Bali (2012) used H_{50} instead of H_s to introduce a new model
  - Data: Both Van der Meer (1988) and Vidal et al. (2006) laboratory measurements
  - Use M5′ algorithm in Model tree (MT) approach to obtain optimum model

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

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 Bali (2012)	0.04	0.12	0.86	0.93

$$BIAS = \sum_{i=1}^{N} \frac{1}{N}(Y_i - X_i)$$

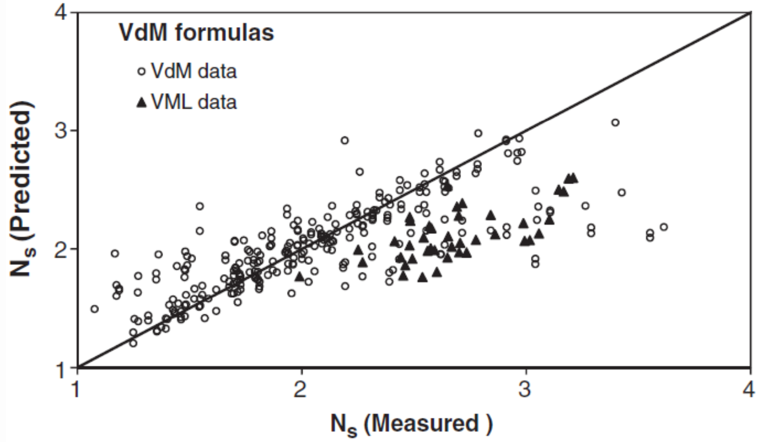
$$SI = \frac{\sqrt{\frac{1}{N}\sum_{i=1}^{N}(Y_i - X_i)^2}}{\overline{X}_i}$$

$$CC = \frac{\sum_{i=1}^{N}(X_i - \overline{X})(Y_i - \overline{Y})}{\sqrt{\sum_{i=1}^{N}(X_i - \overline{X})^2 \sum_{i=1}^{N}(Y_i - \overline{Y})^2}}$$

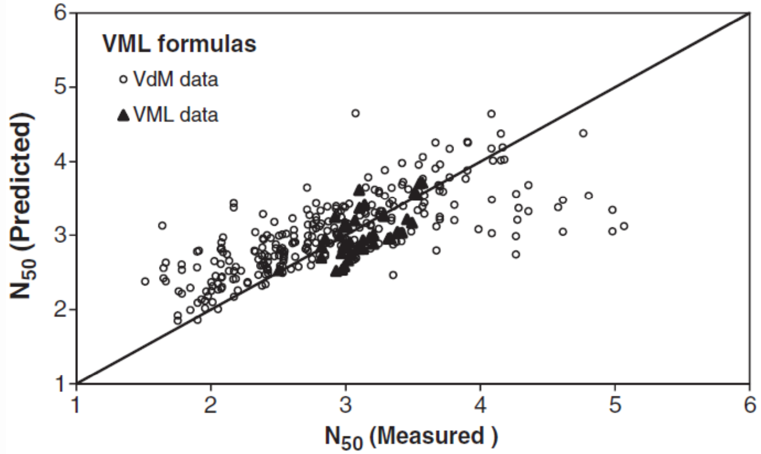
$$I_a = 1 - \frac{\sum_{i=1}^{N}(Y_i - X_i)^2}{\sum_{i=1}^{N}\left(\left|Y_i - \overline{X}\right| + \left|X_i - \overline{X}\right|\right)^2}$$

EQUATION OVERVIEW

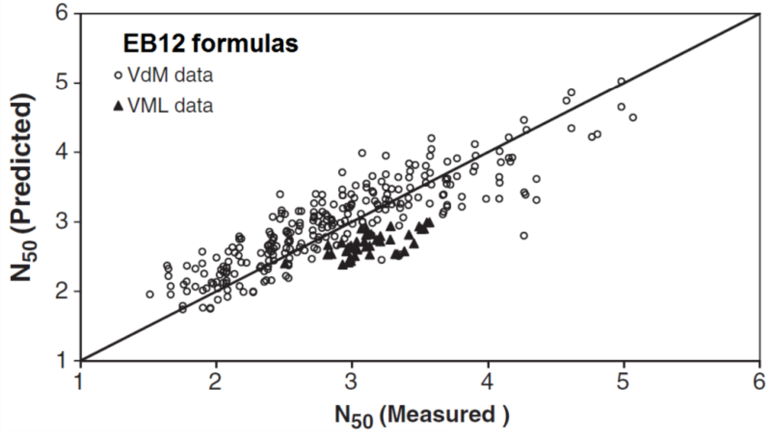
Van der Meer (1988)



Vidal et al. (2006)



Etemad-Shahidi and Bali (2012)



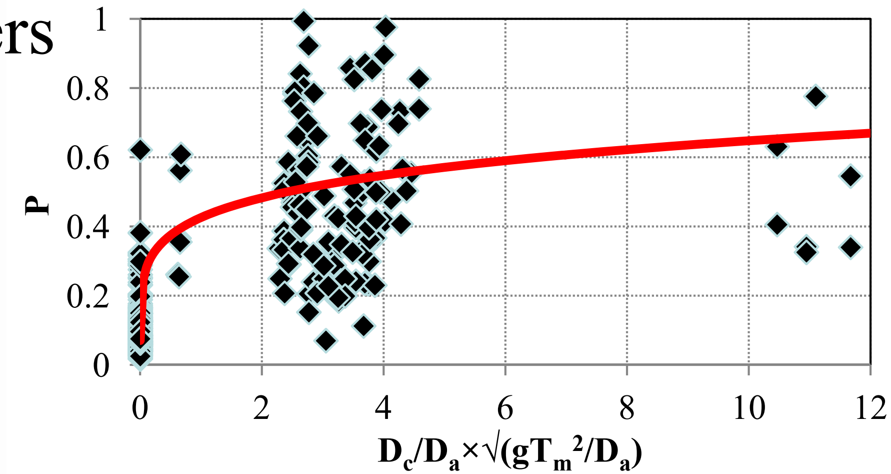
METHODOLOGY & RESULTS

- Use data sets of Van der Meer (1988) and Vidal et al. (2006) laboratory measurements
- Use the Etemad-Shahidi and Bali (2012) formula

$$P = \left(\frac{N_{50}}{4.24 S^{0.17} \xi_m^{-0.4}} \right)^{1/0.18}$$

- Identify the governing parameters through sensitivity analysis
  - Core diameter (D_c), armour diameter (D_A), and the wave period
- Normalize the governing parameters

$$\frac{D_c}{D_A} \qquad \sqrt{\frac{gT_m^{\ 2}}{D_A}}$$



METHODOLOGY & RESULTS

- Data sets is divided into test and train data sets.
- Neural networks approach was used

$$P = f\left(\sqrt{gT_m^2 / D_A}, \left(D_c / D_A\right)\right)$$

- Different equations were obtained with different level of maturity and error.
- The simplest form with relatively smallest error was chosen

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

Any question or comment please