WAVE REFLECTION FROM BERM BREAKWATERS

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INTRODUCTION

Wave reflection from berm breakwaters is an area less focused as these structures are generally considered to have relatively low reflection levels. However, the reflected waves may compromise the stability of the structure by inducing scour at the toe and may enhance harbour access risk (Zanuttigh et al., 2013). Hence, it is necessary that the reflection coefficients are predicted accurately. Several empirical formulas such as Postma (1989), Alikhani (2000), Zanuttigh and Van der Meer (2008) and Van der Meer and Sigurdarson (2016) have been suggested for the prediction of wave reflection, K_r. In this study, physical model tests were conducted to supplement the existing berm breakwater data sets in the CLASH database (Zanuttigh et al., 2016). The measured reflection coefficients were then compared with those of the existing formulas to evaluate their performance.

PHYSICAL MODEL TEST

Two-dimensional model testing was undertaken in the wave flume (18.0 m long x 0.80 m deep x 0.5 m wide) at the hydraulics laboratory of Griffith University, Gold Coast, Australia. Irregular waves were generated using the JONSWAP spectrum with a peak enhancement factor (γ) of 3.3. Tests were conducted on berm breakwaters with cross-sections having an initial slope of 1:1.5 above and below the berm (see Figure 1) for a range of wave steepnesses from 0.02 to 0.06, which has not been studied previously. Three different berm widths of 0.25 m, 0.35 m and 0.45 m were studied with the berm levels varied from -0.075 m to + 0.050 m relative to the still water level.

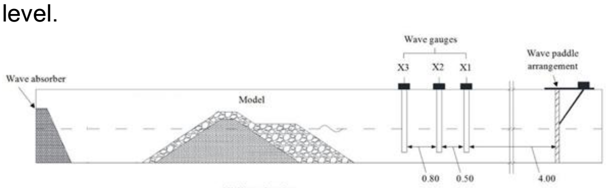


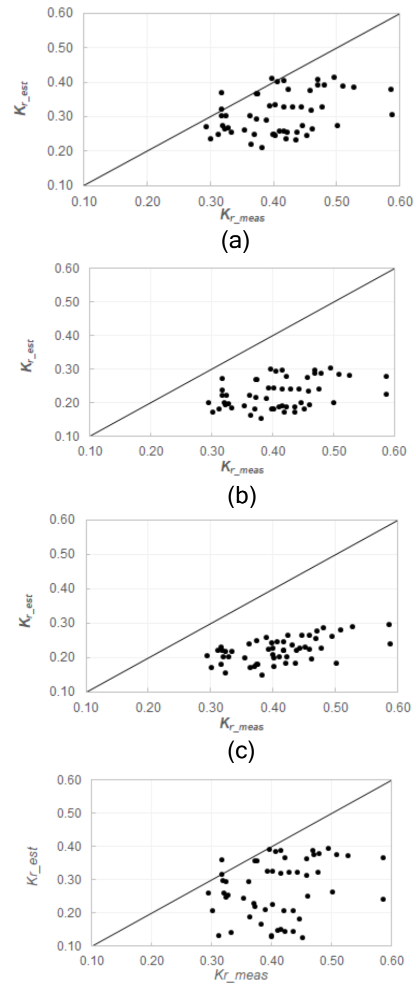
Figure 1 - Schematic cross section of the berm breakwater tested

COMPARISON OF MESURED AND ESTIMATED VALUES

The performances of the existing K_r formulas (Table 1) were examined by comparing the predicted values (K_{r_est}) with the measured data (K_{r_meas}) from the physical model tests (from this study). The results are presented in Figure 2. The solid line indicates perfect agreement between the measured and predicted K_r values.

Table 1 Summary of K_r prediction formulas

Formula	Reference
$K_r = 0.071 P^{0.082} \cot\alpha^{-0.62} s_{0p}^{-0.46}$	Postma (1989) (PO)
$K_r = 0.044 s_{0p}^{-0.46}$	Alikhani (2000) (AK)
$K_r = \tanh(a \xi_0^b)$	Zanuttigh and Van der Meer (2008) (ZV)
$K_r = \begin{cases} 1.3 - 1.7 s_{0p}^{0.15} & H_{m0}/\Delta D_{n50} < 2.5 \text{ or } Rec/D_{n50} < 4 \text{ to } 5 \\ 1.8 - 2.65 s_{0p}^{0.15} & H_{m0}/\Delta D_{n50} > 2.5 \text{ or } Rec/D_{n50} > 4 \text{ to } 5 \end{cases}$	Van der Meer and Sigurdarson (2016) (VS)



(a)

(b)

(c)

(d)

Figure 2 - Comparison of K_{r_meas} and K_{r_est} using the formulas of a) Postma (1989) (PO) b) Alikhani (2000) (AK) c) Zanuttigh and Van der Meer (2008) (ZV) and d) Van der Meer and Sigurdarson (2016) (VS)

From Figure 2, it can be seen that the K_r, (especially K_r >0.4) are predominantly underestimated, which could lead to an underestimate of the actual K_r and therefore a possible risk. The performance of the existing formulas were further compared using the accuracy measures of:

$$\text{RMSE} = \sqrt{\frac{1}{n}\sum_{i=1}^{i=n}\left(K_{r\_est} - K_{r\_meas}\right)^2} \quad (1)$$

$$\text{DR} = \frac{1}{n}\sum_{i=1}^{i=n}\frac{K_{r\_est}}{K_{r\_meas}} \quad (2)$$

$$\text{Bias} = \frac{1}{n}\sum_{i=1}^{i=n}\left(K_{r\_est} - K_{r\_meas}\right) \quad (3)$$

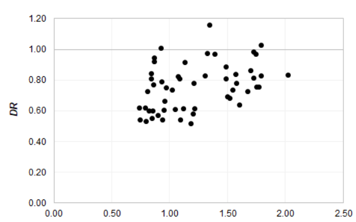
The results of the comparison are presented in Table 2.

Table 2 Accuracy measures of the existing formulas

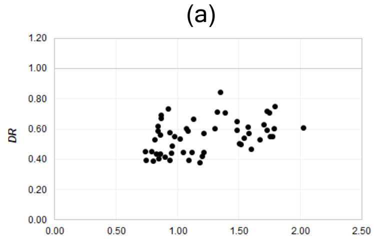
Accuracy	**Formulas**			
	PO	AK	ZV	VS
RMSE	0.13	0.12	0.20	0.17
DR	0.76	0.75	0.54	0.67
Bias	-0.10	-0.10	-0.19	-0.14

The negative *Bias* reflect the underestimation of K_r in Figure 2. An *RMSE* close to zero indicates better estimation of K_{r_meas} and it can be seen that some of the earlier formulas such as Postma (1989) and Alikhani (2000) performs better than the more recent ones. A *DR* value close to 1 indicates that the measured and estimated values are close to each other and again the Postma (1989) and Alikhani (2000) formulas perform better than the others. A reason for this could be that the Postma (1989) and Alikhani (2000) formulas include mostly the primary governing variables while the others include more structural and hydraulic parameters. In addition, the latter are developed from a database that is less representative of berm breakwaters.

In Figure 3, *DR* of the existing formulas is plotted against dimensionless crest freeboard (R_c/H_{m0}). If the variable is incorporated well in the formula, the points will be close to the horizontal line at *DR* = 1. However, all of the existing formulas present large scatters (predominantly underestimation of the order of up to 80%) which shows that the existing formulas could be improved by considering additional dimensionless governing variables.



(a)



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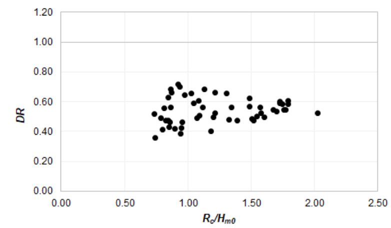
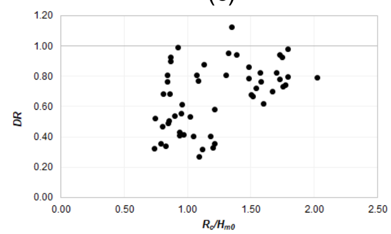


(c)



(d)

Figure 3. Variations of *DR* as a function of R_c/H_{m0} using the formulas of a) Postma (1989) b) Alikhani (2000) c) Zanuttigh and Van der Meer (2008) and d) Van der Meer and Sigurdarson (2016)

CONCLUSION

The study developed wave reflection data of berm breakwaters which complements the existing database of reflection coefficients. The performance of the existing formulas in predicting K_r was studied both qualitatively and quantitatively. The results demonstrate that the formulas show some inaccuracies in estimating wave reflection coefficients and mostly underestimating the measured reflection which could adversely affect the safety of berm breakwaters. The newly acquired data could be used to improve the reliability of the prediction formulas.

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