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An effective approach to calibrate numerical modelling of wave interaction with thin perforated plate using data-driven method

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INTRODUCTION AND AIMS

Linear and non-linear drag coefficients (α, β) are both important in simulation of wave and porous structures using macroscopic approach. It is still large uncertainty in describing those parameters.

$$I = \frac{\alpha\nu(1-n)}{n^2 D_{50}^2}\vec{u} + \frac{\beta(1-n)}{n^2 d_{50}}\vec{u}|\vec{u}|$$

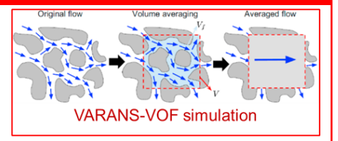
Aims of the work are

- to propose a time-efficient approach to determine optimal combination of α and β
- to simulate the interaction between thin perforated plate as breakwater and different wave conditions

METHODS

The proposed approach consists of:

a) NWT with and without porous plates using IH2VOF model based on VARANS-VOF equations for data generation
b) Gradient boosting decision trees method with multi-output regression used as prediction model
c) Experimental data from literature [1]
d) MSE criterion for estimate the optimal model parameters



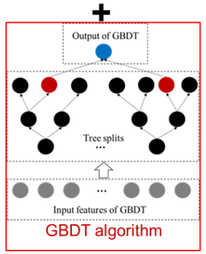
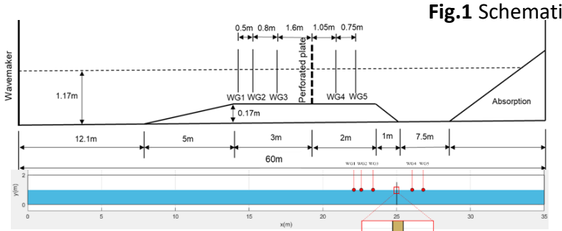
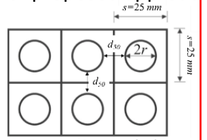


Fig.1 Schematic of proposed approach





$$n = \frac{\pi r^2}{s^2}$$

Fig.2 Physical and numerical model

[1] D. Qiao et al., "Numerical analysis on wave load reduction effect of a solid wall with porous plate by macroscopic CFD approach," Ocean Engineering, vol. 237, p. 109624, 2021.

APPROACH DEVELOPMENT

The prediction model are developed as follows:

a) A limited sample (72 cases) used for training and testing
b) Wave characteristic were scaled according to Froude's law
c) Multi-outputs regression in XGBoost was used
d) $T_{p,\,in\_scaled}$, n, α, β as be input features; K_r and K_t as be output values
e) High regression coefficient (R^2) is achieved

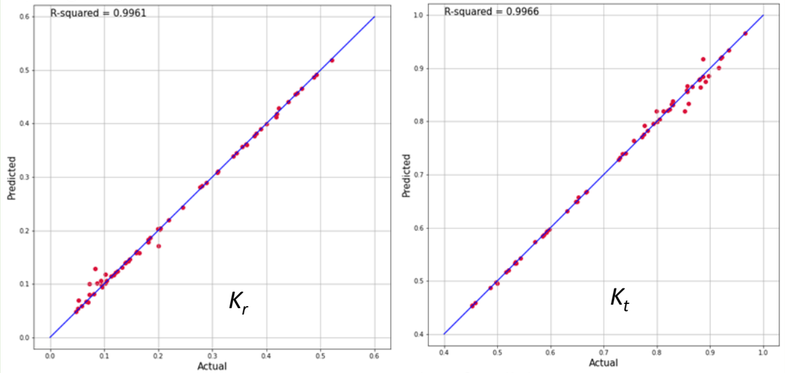


Fig.3 Regression analysis for all dataset

The estimation of model parameters:

a) Developed model is then used to estimate possible combination of IH2VOF model parameters
b) Smallest difference between predicted and experimental data resulting the best estimation
c) Best combination consisting of α=100 and β=0.3 is then applied for IH2VOF modelling

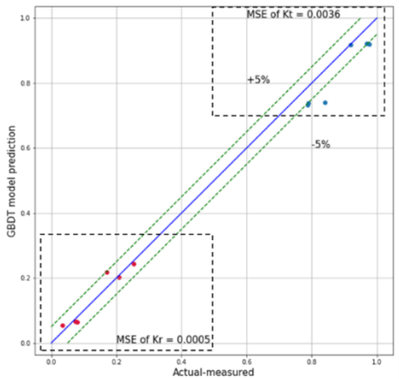


Fig.4 Prediction model vs experiment

RESULTS

- Numerical results in term of free surface elevation measured in front of (WG1) and behind (WG4) structure are compared with available experimental ones.
- A good agreement has been found

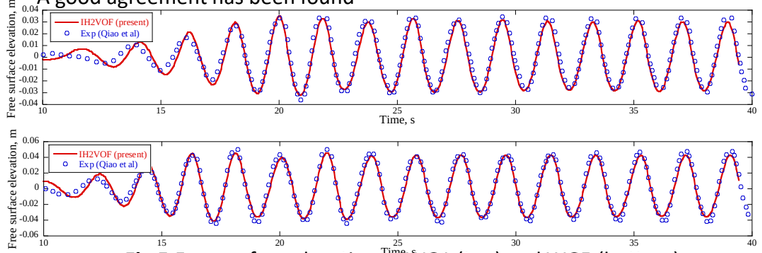


Fig.5 Free surface elevation at WG1 (top) and WG5 (bottom)

- Adopting established model to investigate wave transmission and reflection for different wave conditions, then compared with experimental data

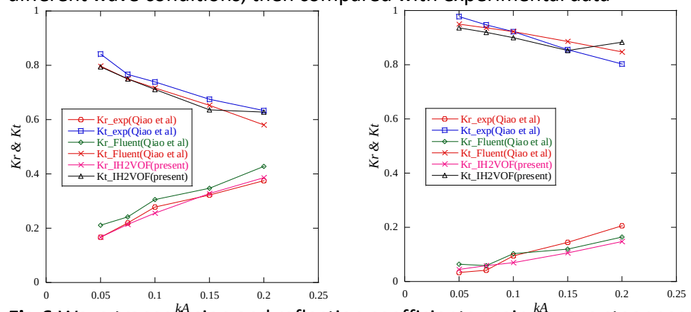


Fig.6 Wave transmission and reflection coefficients against wave steepness *kA*

CONCLUSIONS

The prediction model are developed as follows:

- A time-efficient approach to calibrate VARANS-VOF model for interaction between wave and thin perforated breakwater was proposed
- A prediction model for wave transmission and reflection coefficients was presented.
- A highly accurate numerical model for simulation of wave and thin perforated breakwater has been established.

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