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VALIDATION OF A NONLINEAR WAVE DECOMPOSITION METHOD INCLUDING SHOALING

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1 INTRODUCTION

It is important to decompose the incident and the reflected waves when performing physical or numerical experiments in a wave flume. Especially when large reflection is expected, from for example a breakwater, the total measured signal can significantly deviate from the incident signal.

Different techniques exist to decompose a signal into incident and reflected signals. For 1D wave flumes a method based on co-located wave gauges (Nwogu, 1989) or multiple wave gauges (Røge Eldrup and Lykke Andersen, 2019, Zelt and Skjelbreia, 1993) is commonly applied. The latter is the focus of this abstract since recently, the decomposition method based on multiple wave gauges was extended to be applicable to nonlinear irregular waves by including bound waves and amplitude dispersion (Eldrup and Lykke Andersen, 2019). Moreover, the practical requirements for the nonlinear wave decomposition methods were described in De Ridder et al. (2023).

Most of the nonlinear wave decomposition methods are only applicable to a flat bed and will introduce an error when it is applied on a sloping foreshore which is typically the case in physical model experiments. Padilla and Alsina (2020) derived a general framework including shoaling of bound waves and Lykke Andersen and Eldrup (2021) presented a method for nonlinear regular waves over a sloping bed. However, a nonlinear decomposition method for irregular waves over a sloping bed has never been verified with physical model experiments.

In this abstract the nonlinear decomposition method for irregular waves as presented in De Ridder et al. (2023) is extended with the effects of shoaling and its effects are verified with a physical model experiment.

2 Theory

The nonlinear wave decomposition method as described in De Ridder et al. (2023) is extended to include the effect of shoaling by (1) using a spatially varying phase and (2) adding a shoaling coefficient. In essence the following system of equation is solved for each frequency to decompose the signal without the effects of shoaling,

$$\begin{bmatrix} 1 & 1 & 1 & 1 \\ e^{-ik\beta_{in}x_{12}} & e^{+ik\beta_{re}x_{12}} & e^{-ik_B\beta_{in}x_{12}} & e^{+ik_B\beta_{re}x_{12}} \\ \dots & \dots & \dots & \dots \\ e^{-ik\beta_{in}x_{1N}} & e^{+ik\beta_{re}x_{1N}} & e^{-ik_B\beta_{in}x_{1N}} & e^{+ik_N\beta_{re}x_{1N}} \end{bmatrix} \begin{bmatrix} \hat{a}_{in,F} \\ \hat{a}_{re,F} \\ \hat{a}_{in,B} \\ \hat{a}_{re,B} \end{bmatrix} = \begin{bmatrix} \hat{\zeta}_1 \\ \dots \\ \widehat{\zeta_N} \end{bmatrix} \qquad (1)$$

where k is the free wave number, k_B is the bound wave number, β_{in} the amplitude dispersion factor for incident waves, β_{re} the amplitude dispersion factor for reflected wave, $\hat{a}_{in,F}$ the incident free complex wave amplitude, $\hat{a}_{in,B}$ the incident bound complex wave amplitude, $\hat{a}_{re,F}$ the reflected free complex wave amplitude, $\hat{a}_{re,B}$ the reflected bound complex wave amplitude, ζ_j the measured complex wave amplitude at wave gauge j for $j=1\dots N$ and x_{1J} the distance between wave gauge j and the first wave gauge. To include the effect of a spatially varying phase, the phase, $\theta(x)$, is computed at position x as follows:

$$\theta(x) = \int_{x_1}^{x_j} k(x)dx \qquad (2)$$

where $k(x)$ is the wave number and x_1 the first wave gauge position and x_j the wave gauge position at location j. This phase shift replaces the bound or free wave number times the wave gauge spacing (kx_{12}) in Equation 1. The second adjustment is including a shoaling coefficient in Equation 1 to correct for the energy transformation over the slope. For the free components linear shoaling is assumed ($K=c_{g0}/c_{g1}$), and for the bound waves the shoaling coefficient ($K=(h_0/h_1)^{\alpha}$) as described in Padilla and Alsina (2020) is used. The effects of a regular wave are shown in Figure 1, where both the linear and bound shoaling coefficient (second panel) are shown.

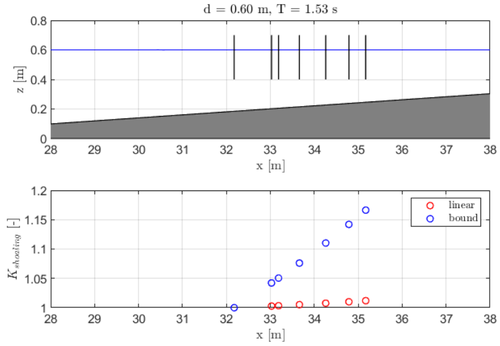

Figure 1. Shoaling coefficient (second panel) for a synthetic wave with a period of 1.53 s. Locations of the wave gauges and the bed level are shown in the first panel.

3 Method and Results

The method described in De Ridder et al. 2023 (Ref.) and the adjusted wave decomposition method (Shoaling) were both applied to a physical model experiment (H_{m0}=0.2m, T_p=1.5s, d=0.6m) with a foreshore (1:50). Seven wave gauges were used to decompose the measured signal into incident and reflected signals for both methods (see Table 1). A typical rubble mount breakwater is placed in the flume to create reflections. For a detailed overview of the experiments and the physical model setup see de Ridder et al. (2023).

Table 1. Incident wave parameters obtained with the two methods (Ref. and Shoaling).

	$H_{m0,in}$ [m]	$H_{2\%,in}$ [m]	$T_{m-1,0,in}$ [s]	$T_{m02,in}$ [s]
Ref	0.171	0.195	1.734	1.272
Shoaling	0.169	0.192	1.71	1.289

4 CONCLUSIONS

A nonlinear decomposition method for nonlinear waves is extended to include the effects of a sloping foreshore. The method is adjusted by including a spatially varying phase and a shoaling coefficient for both the free and bound waves. A validation with a physical model experiment over a sloping foreshore shows that the method including the shoaling model results in a lower wave height for the first wave gauge. In the final work, the verification of the method will be extended for more tests and the applicability range will be added.

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