TRANSFORMATIONS OF WAVE SPECTRA ON MUDDY BEDS

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The attenuation of various wave spectra on soft muddy beds is examined through numerical simulation and laboratory experiments. A series of laboratory wave-flume experiments are conducted to study the transformations of different wave spectra travelling along the fluid mud layer. Commercial kaolinite was used as bottom mud layer, and its rheological flow curves of shear stress versus shear rate were obtained by controlled shear rate tests. Assuming viscous behavior for the fluid mud layer, a wave-mud interaction model was employed to simulate the dissipation of wave spectra. Comparisons between the measured data and numerical results reveal that the wave spectra approach offers an acceptable approximation for irregular wave attenuation on muddy beds.

INTRODUCTION

Wave dissipation over fluid mud has been observed in a number of coastal regions including coastal waters of Surinam, Guyana Coast, Kumamoto Port at Ariake Sea of Japan, Coast of Kerala in India, Cassino Beach in Brazil and Northwest part of the Persian Gulf in Iran. Although the irregularity of waves plays an important role in wave evolution in these muddy coasts, the experimental and numerical studies on irregular wave transformation on muddy beds are limited (e.g., Zhao and Li 1994, Soltanpour et al. 2007, Niu and Yu 2008). The present study aims to investigate the attenuation of wave spectra as one of the major components of irregular wave-mud interaction.

NUMERICAL MODELING

The dynamic behavior of fluid mud response to periodic wave action is an important factor in numerical modeling of energy dissipation of waves over muddy beds. Different constitutive equations have been assumed for prediction of the response of muddy beds. In a simple assumption, here the fluid mud is treated as a viscous fluid with a greater viscosity and higher density than water. The constitutive equation of a viscous fluid is represented as follows:

\[
\sigma_{ij} = -p \delta_{ij} + 2\mu \dot{e}_{ij}
\]  

(1)

where $p$ is the mean or the hydrostatic stress, $\mu$ is the dynamic viscosity $\delta_{ij}$ is the Kronecker delta, and $\dot{e}_{ij}$ is the strain rate tensor. Employing Anton Paar Physica MCR300 rheometer, controlled shear rate tests were conducted to obtain the rheological parameters of fluid mud.

A multi-layered fluid system including the viscous water layer and fluid mud sub-layers was used to compute the wave attenuation rate. The wave spectra modeling approach was employed for the simulation of irregular waves. The irregular waves are decomposed as an infinite number of regular wave components with different wave energy (amplitudes and frequencies). The wave spectra are defined as below:

\[
S(f) = \frac{1}{\Delta f} \sum_{n=1}^{\infty} \frac{1}{2} a_n^2
\]  

(2)

where $S(f)$ is spectral density, $f$ is frequency, and $a_n$ is the amplitude of the $n$th wave component. Based on the exponential decay of wave height over muddy bed, the modeling spectra at point $x$ will become:

\[
\tilde{S}(\tilde{f}_n) = \tilde{S}_0(\tilde{f}_n)e^{-2\beta_x(x-\tilde{x}_n)}
\]  

(3)
where \( S_n(f) \) is the average value of spectra at \( x=x_0 \), and \( k_{in} \) is the wave attenuation coefficient of the \( n \)th wave component.

**LABORATORY INVESTIGATIONS**

The experiments were carried out in a wave flume at the Hydraulic Model Laboratory, Department of Civil Engineering, K. N. Toosi University of Technology. Fig. 1 shows the sketch of experimental setup. Various wave spectral shapes (i.e. Pierson-Moskowitz, JONSWAP and Neumann) with different wave heights and frequencies were applied.

![Fig. 1 Sketch of experimental setup, units in m](image)

**RESULTS AND CONCLUSION**

Fig. 2 shows an example of the wave energy density versus frequency at measuring wave gauges, and the computed and measured wave spectra along the laboratory flume where \( x=7.9 \) m is taken from the beginning of mud bed. In spite of the observed discrepancies, the comparisons reveal that wave spectra modeling can be applied for irregular wave attenuation on mud beds.

![Fig. 2 a) Measured wave spectra at wave gauges b) Measured and computed wave spectra at the last gauge](image)

**REFERENCES**

