MANGROVE AND ITS IMPACTS ON WATER WAVES: A MODEL-SCALE LABORATORY STUDY USING 3D REPLICAS OF TYPICAL RHIZOPHORA

Che-Wei Chang, Disaster Prevention Research Institute, Kyoto University, chang.chewei.5z@kyoto-u.ac.jp
Nobuhito Mori, Disaster Prevention Research Institute, Kyoto University, mori@oceanwave.jp
Naoki Tsuruta & Kojiro Suzuki, Port and Airport Research Institute, tsuruta-n@p.mpat.go.jp & suzuki_k@p.mpat.go.jp
Hideaki Yanagisawa, Tohoku Gakuin University, h-yanagi@mail.tohoku-gakuin.ac.jp

INTRODUCTION

Mangroves, a major type of nature-based solution in the tropics and subtropics, were evidenced capable of reducing wave energy in tsunami and storm events. The typical species, Rhizophora with its complex root system, was found effective in wave attenuation (Tanaka et al. 2007) and was studied experimentally using artificial tree models (e.g. Maza et al. 2019). To investigate the impacts of mangrove roots on water waves at a finer scale, we conducted experiments using 3D-printed models that replicated the geometry of natural Rhizophora. This study discusses the resistance of mangrove roots and their impacts on fluid velocity and turbulence.

EXPERIMENTAL SETUP

Based on the scanned images of typical *Rhizophora* species obtained from fields (e.g., Fig.1), we used 3D-printed trees to build up the model forest. Different arrangements of mangrove models and stem densities were adopted. We also investigated the impacts of the submergence of mangrove roots on water waves under different water depths. Testing regular, irregular and solitary waves of various incident conditions, we used ADVs to measure the fluid velocity. To investigate the relationships between mangrove-induced resistance and hydrodynamic conditions, we applied the approach of direct force measurement, directly measuring wave forces exerting on the 3D tree model. Multiple wave gauges were installed to record the wave evolution along the forest.

MANGROVE-INDUCED RESISTANCE

Based on the Morison-type equation, the wave forces can be expressed as a summation of drag force and inertia force:

$$F = \frac{1}{2(\eta + h)} C_D \int_{-h}^{\eta} u|u| \mathrm{dA} + \frac{1}{\eta + h} C_M \int_{-h}^{\eta} \frac{\partial u}{\partial t} \mathrm{dV} \quad (1)$$

In the above Eq.(1), η and h are the free surface elevation and water depth; A and V represent the projected frontal area and the submerged volume of mangroves, respectively. For each test condition, we estimate the drag coefficients C_D and inertia coefficient C_M based on the measured forces and fluid velocity. The empirical formulas of the force coefficients were then proposed as functions of dimensionless flow parameters, i.e. Reynolds number and Keulegan-Carpenter numbers (Fig.2). More results will be presented at the conference.

FLUID VELOCITY AND TURBULENCE

We also investigated the impact of mangrove roots on fluid velocity and turbulent kinetic energy. As shown in Fig.3, we observed significant fluctuation of fluid velocity and the enhancement of turbulent kinetic energy at several particular vertical positions, which showed the blockage effects of mangroves and the shear-induced turbulence due to the complex root structure. More details will be discussed at the conference.

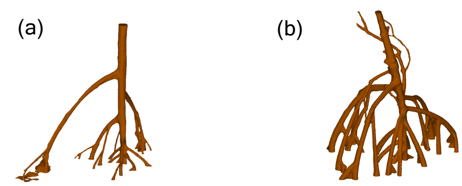

Figure 1 - Two typical Rhizophora species: (a) Rhizophora Apiculata and (b) Rhizophora Stylosa.

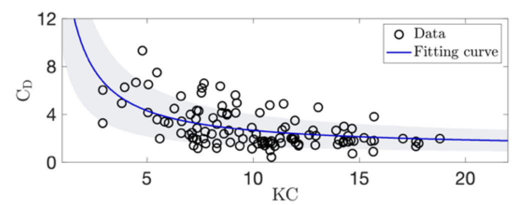

Figure 2 - An example of the estimated drag coefficients in terms of Keulegan-Carpenter number for regular-wave tests. Solid line shows the best-fitting curve.

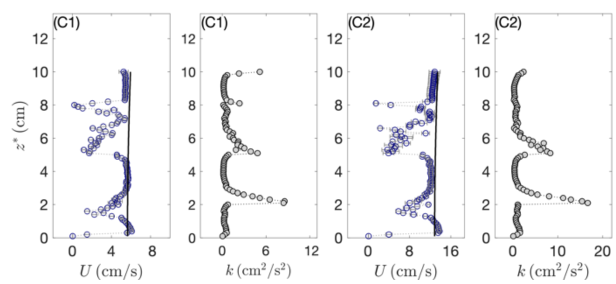

Figure 3 - Measured fluid velocity U and turbulent kinetic energy k for two representative regular-wave cases. In the fluid velocity profiles, solid lines show the amplitude of the linear-wave velocity. $z^* = 0$ indicates the flume bed.

REFERENCES

Maza, Lara and Losada (2019): Experimental analysis of wave attenuation and drag forces in a realistic fringe Rhizophora mangrove forest, Advances in Water Resources, ELSEVIER, vol. 131, pp. 103376.

Tanaka, Sasaki, Mowjood, Jinadasa, and Homchuen (2007) Coastal Vegetation Structures and Their Functions in Tsunami Protection: Experience of the Recent Indian Ocean Tsunami, Landscape and Ecological Engineering, SPRINGER, vol. 3, pp.33-45.