EXPERIMENTAL STUDY OF MANGROVE EFFECTS ON COASTAL PROTECTION

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
Mangrove forests, featured by the complex root system, were found effective among natural-based solutions in coastal disaster reduction (e.g. Guannel et al. 2016). The prop roots of mangroves have been deemed useful in attenuating waves and were addressed in several recent experimental works using artificial tree models (e.g. Maza et al. 2019). In this study, laboratory experiments were conducted on both model scale and prototype scale using more realistic models. We aim to provide a comprehensive investigation of wave-induced forces exerted on mangroves and propose proper relationships of force coefficients with flow parameters under various incident conditions. The correlation between the model scale and the prototype scale, which is unsolved but essential for future model developments and practical applications, is also discussed in this work.

EXPERIMENTAL SETUP
Two sets of experiments on model scale and prototype scale were conducted at the Port and Airport Research Institute in Japan. For the model-scale tests, the exact geometry of a real mangrove was scaled down (1:7) based on a scanned image of a typical Rhizophora Apiculata (Fig.1). Following the Froude similarity, 3D-printed trees were used to build up the model forest. In the experiments, ADVs and a directional force transducer were employed to measure the fluid velocity and wave-induced forces on tree models. Multiple wave gauges were installed to capture the wave amplitude evolution along the forest. Individual-tree tests were also conducted as comparison groups to evaluate the impacts of interactions between trees. For the prototype-scale tests, we used real trees (Rhizophora Stylosa in Fig.1) from the field and focused on the individual-tree tests. Likewise, the wave forces exerting on the mangrove were measured by the force transducer at the bottom of the tree and the pressure gauges along the trunk. Several accelerometers, attached on the trunk, plus video cameras were used to record the swing of the tree under larger waves. This provided a further investigation of the flexibility of real mangroves under extreme wave conditions. A loading test was also conducted to estimate the bending modulus of the tree. In both sets of experiments, different water depths were tested, allowing a systematic study of the impacts by the submerged ratio of the root system. Different types of waves (e.g. regular/solitary waves) along with various incidence conditions were also tested.

DATA ANALYSIS AND RESULTS
Based on the Morison-type equation, the drag and inertia coefficients were firstly estimated from the experimental data. An example of the predicted forces by Morison formula comparing with the measurements for model-scale tests is presented in Fig.2. Overall, good agreements were found for all the testing cases. It was also observed that inertia forces were not negligible even for longer periodic waves. Therefore, both drag and inertia effects should be taken into account for more accurate prediction of wave forces. With the validation of predicted forces, new formulas of force coefficients in terms of dimensionless parameters can be proposed. Fig.3 shows an example of the model-scale results using the trunk diameter at breast height (D_{BH}) in Reynolds and Keulegan-Carpenter numbers. Different definitions and formulas for both scales were also proposed. More results including the correlation between the model scale and prototype scale will be discussed in the conference. In addition to the present study, field measurements, with the use of a latest 3D laser scanner, are currently ongoing, which will help establish a useful database of the detailed shapes of the root system for future study.

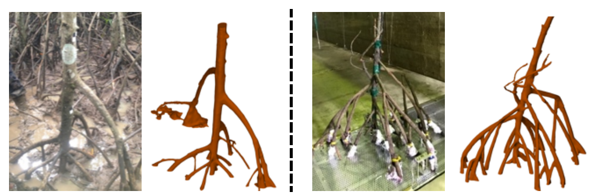

Figure 1 - Mangrove trees and the 3D-scanned images. Left: Rhizophora Apiculata; right: Rhizophora Stylosa

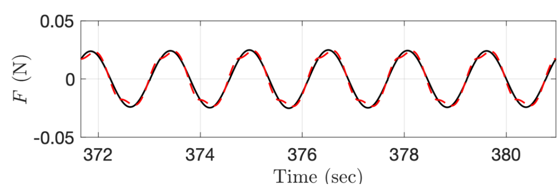

Figure 2 - A comparison of predicted force (red dashed line) with measured force (black solid line) - regular waves

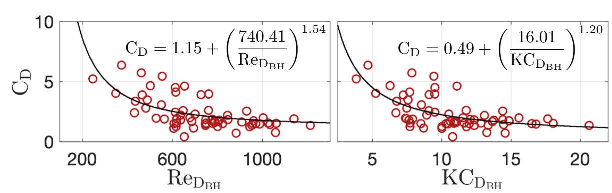

Figure 3 - Drag coefficients vs. Reynolds/KC numbers

REFERENCES
Guannel et al. (2016): The power of three: coral reefs, seagrasses and mangroves protect coastal regions and increase their resilience, PloS one, vol.11, pp. 1-22.
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.