ARE REDUCED-SCALE EXPERIMENTS OF WAVE DAMPING BY VEGETATION SUITABLE FOR ENGINEERING WITH NATURE?

Daniel Cox, Oregon State University, Dan.Cox@oregonstate.edu
Kiernan Kelty, cbec eco engineering, k.kelty@cbecoeng.com
Pedro Lomonaco, Oregon State University, Pedro.Lomonaco@oregonstate.edu
Tori Tomiczek, US Naval Academy, vjohnson@usna.edu
Kayla Ostrow, Oregon State University, ostrowk@oregonstate.edu

INTRODUCTION

Wave damping by vegetation has been included in many numerical models for coastal engineering primarily through a parameterized expression for the wave height decay following Mendez and Losada (2004), given by

$$\tilde{\alpha} = \frac{\overline{A_t}\, N\, H_{rms,i}\, C_D k_p}{3\sqrt{\pi}} \frac{\sinh^3(k_p d) + 3\sinh(k_p d)}{\sinh(k_p h)\,(\sinh(2k_p h) + 2k_p h)}$$

where $\tilde{\alpha}$ is the wave height decay rate, $\overline{A_t}$ is the mean projected area of the vegetation, N is the number of vegetation elements per unit area, H_{rms} is the root mean square wave height, k_p is the wavenumber based on the peak wave period, d is the mean wetted height of the vegetation, and h is the water depth.

C_D is an empirical coefficient often derived from reduced-scale laboratory experiments in which $\tilde{\alpha}$ is measured directly. Multiple values of C_D can be determined from a series of tests with variations to $\overline{A_t}$, N, H_{rms}, etc.; and C_D is often given as a function of the Reynolds number, Re, as

$$C_D = a_1 + (a_2/Re)^{a_3}$$

where a_1, a_2 and a_3 are fitted over the range of tests, and $Re = \rho UD/\mu$ is defined with fluid density ρ and dynamic viscosity μ. The characteristic velocity U is often taken as the maximum horizontal wave-induced velocity, and the characteristic length scale D is often taken as the stem diameter of the vegetation.

These empirical relations for C_D are subsequently used along with the vegetation and wave properties to estimate the wave damping rate in numerical models.

Although C_D has been shown to have a Reynolds-dependence, it is well known that Reynolds similitude cannot be held between model and prototype when Froude similitude is applied. This disparity raises a fundamental scaling issue to be explored in this paper:

Are drag coefficients obtained by reduced-scale experiments of wave damping by vegetation suitable for engineering design?

PROTOTYPE SCALE EXPERIMENTS

To address this issue, we conducted prototype-scale laboratory tests of wave damping for an idealized mangrove forest of moderate cross-shore width (Kelty et al., 2022) and compared results to two reduced-scale tests conducted independently by other researchers. Figure 1 (top) shows a direct comparison of the C_D vs Re highlighting the *Re* dependent scaling issues. Figure 1 (bottom) shows a rescaling of Re considering Froude similitude, given as

$$Re_p = Re_m \lambda^{\frac{3}{2}}$$

where λ is the geometric scale ratio.

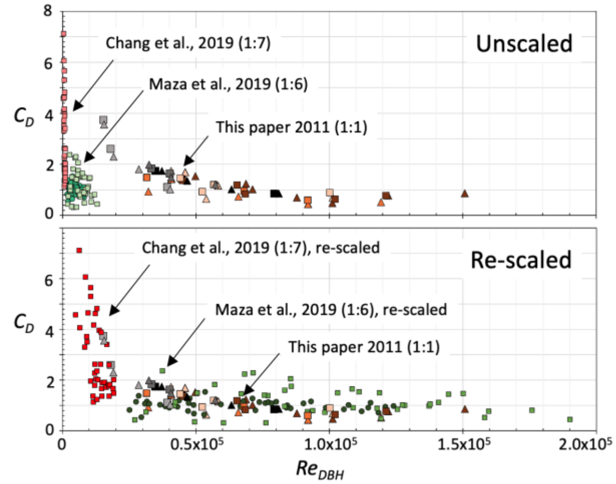

Figure 1: Issues with reduced-scaled physical models to derive empirical relations for C_D as a function of Re.

CONFERENCE PRESENTATION

At the conference, we will present the details of our prototype-scale tests, the quantification of the complex mangrove root structure $\overline{A_t}$ using LiDAR, the uncertainty quantification of C_D for these tests, data archive and open access, and propose the scaling relation for future tests. The implication of the use of unscaled and re-scaled damping coefficients for models like XBeach will be presented and discussed in the context of coastal engineering design.

REFERENCES

Kelty, Tomiczek, Cox, Lomonaco, Mitchel (2022) Prototype-scale physical model of wave attenuation through a mangrove forest of moderate cross-shore thickness: LiDAR-based characterization and Reynolds scaling for engineering with nature, *Frontiers in Marine Science*, doi.org/10.3389/fmars.2021.780946.

Mendez and Losada (2004). An empirical model to estimate the propagation of random breaking and nonbreaking waves over vegetation fields. *Coastal Engineering* doi: 10.1016/j.coastaleng.2003.11.003