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

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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

\[ \tilde{a} = \frac{\overline{A}_r N H_{rms,i} C_D k_p}{3\sqrt{\pi} \sinh{(k_p d)}} \frac{\sinh{(k_p d)} + 3\sinh{(2k_p h)}}{\sinh{(2k_p h)}} \]

where \( \tilde{a} \) is the wave height decay rate, \( \overline{A}_r \) 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 \( \tilde{a} \) is measured directly. Multiple values of \( C_D \) can be determined from a series of tests with variations to \( \overline{A}_r, N, H_{rms} \), 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 \( \rho \) and dynamic viscosity \( \mu \). 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](image)

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

\[ Re_p = Re_m \lambda^{3/2} \]

where \( \lambda \) is the geometric scale ratio.

CONFERENC PRESENTATION

At the conference, we will present the details of our prototype-scale tests, the quantification of the complex mangrove root structure \( \overline{A}_r \) 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 rescaled 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)