Physical Model Investigation of Parcel Scale Mangrove Effects on Flow Hydrodynamics and Pressures and Loads in the Built Environment

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IMPORTANCE

Rising seas, tropical cyclones, and tsunamis threaten increasingly populated coastal areas, leaving coastal communities searching for sustainable, resilient adaptation solutions to mitigate the impacts of chronic and acute coastal flood hazards. While various hazard mitigation alternatives spanning the grey-green engineering spectrum have been identified, an emerging body of literature has identified natural and nature based features as not only effective in attenuating waves and water levels over land, but also a critical provider of other co-benefits including carbon storage, habitat, and recreation. However, uncertainty about the engineering performance of these systems limits their widespread application in coastal planning and design.

This work specifically investigates parcel-scale effects of the *Rhizophora mangle* (red mangrove) species during extreme wave and/or storm surge conditions. Red mangroves are typically found in tropical and subtropical coastal and brackish waters, noted for their salt tolerance and complex system of prop roots extending from the trunk. While previous studies have quantified wave attenuation and drag coefficients associated with large-scale (>1 km cross-shore) mangrove forests, little is known about the parcel-scale (10-50 m cross-shore) effects of these shoreline systems that are commonly found fronting developed areas such as the Florida Keys.

1:16 SCALE PHYSICAL MODEL

We constructed 100 physical models of the *Rhizophora* species' trunk-prop root system on a 1:16 scale based on a parameterization presented by Ohira et al. (2013), who idealized the mangrove trunk and prop roots based on extensive field measurements. Each mangrove trunk was formed from a 1.3 cm PVC rod, with 11 holes along the trunk in a 45° spiral pattern at 1.3 cm vertical increments to an elevation of 15.2 cm above the base of the trunk. Galvanized steel wire (d = 2.5 mm) was threaded through the holes to form prop roots and bonded to the trunk with cyanoacrylate.

Tests were conducted in Oregon State University's Directional Wave Basin (DWB). Mangroves were placed in staggered rows shoreward of an idealized urban community. Three configurations were considered: M0, M4, and M8, with cross-shore thicknesses (trunk to trunk) of 0, 0.51, and 1.19 m, respectively (corresponding with 0, 8.2, and 19.0 m cross-shore distances at full scale). For each configuration, irregular and transient (tsunami-like) wave trials were conducted with and without the presence of a background current; for each trial, wave gauges, acoustic Doppler velocimeters, pressure gauges, and load cells measured water surface elevations, velocities, pressures on idealized structures, and forces on idealized structures, respectively. Figure 1 shows a side view of the M8 configuration during a transient wave trial with amplitude A=0.20 m and representative period T_R=5.72 s.

Figure 1 - Transient wave interacting with mangroves and idealized urban environment

RESULTS

The presence of mangroves significantly affected both hydrodynamic conditions near the mangroves and pressures and forces on inland structures. Figure 2 presents a summary of the percent reduction in lateral force (compared to the M0 baseline configuration) measured by a six-degree of freedom load cell for all transient wave trials, plotted against the mangrove cross-shore thickness. As shown in the figure, increasing the mangrove cross-shore thickness from 0 rows to 4 rows reduced the total force by 11-49%. Doubling the cross-shore thickness of mangroves further reduced F_x compared to the baseline configuration, with additional load reductions of 4-24% observed from the M4 to M8 configurations.

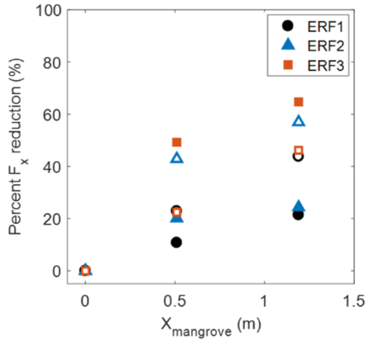

Figure 2 - Percent reduction in F_x on inland structure vs. mangrove cross-shore thickness.

These experiments were part of a larger experimental campaign in OSU's DWB investigating macro-roughness, seawalls, debris, and vegetation, and can inform the engineering performance and design of natural and hybrid systems.

REFERENCES

Ohira, W., Honda, K., et al. (2013): Mangrove stilt root morphology modeling for estimating hydraulic drag in tsunami inundation simulation. Trees, 27 (1), 141-148.