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EXPERIMENTAL AND NUMERICAL INTER-COMPARISON ON GREEN AND GRAY MITIGATION ALTERNATIVES IN FLOODING REDUCTION IN COASTAL REGION

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1 INTRODUCTION

Coastal communities in low-lying regions are increasingly vulnerable to severe flooding triggered by high surges and large waves. The sea level rise resulting from climate change induces shorelines to encroach onto coastal land, further exacerbating the flooding damage in coastal areas. Thus, it is necessary to implement coastal structures to mitigate the influence of extreme flooding events on coastal communities. Seawalls, submerged breakwaters, and mangrove forests have been widely constructed worldwide to attenuate wave overflows and their impact on near-coast regions. However, studies on the comprehensive inter-comparison of the protective performance of each measure against flooding events to provide guidelines in coastal design and planning have yet to be limited. Therefore, experimental and numerical models were conducted to investigate the efficiency of natural (mangrove forests) and man-made (seawall and submerged breakwater) coastal structures in reducing the forces, pressures, and hydrodynamics generated by overflows in constructed environments.

2 METHODOLOGY

A series of laboratory experiments, using a scale of 1:16, were conducted in the Tsunami Wave Basin (48.8 m long, 26.5 m wide, and 2.1 m deep) at Oregon State University. Figures 1a, 1b, and 1c illustrate the plan and profile views of the physical bathymetry and the positions of instruments utilized in the current experiment. The bathymetry is divided into three sections: an 11.7-m offshore area, a 20-m sloping beach, and a 10-m elevated constructed environment characterized by a series of building arrays. Offshore piston-type wavemakers can generate transient waves with amplitudes (A) ranging from 0.11 m to 0.21 m and different surge levels (d) between 0.98 m and 1.1 m. Offshore wave gauges (WGs), ultrasonic wave gauges (USWGs), acoustic Doppler Velocitmeters (ADV), loadcells (LC), and pressure gauges (PGs) were installed offshore, onshore positions, and built-in building elements to measure the incident wave height, inundation depth, velocity, force, and pressure, respectively. A detailed description is presented in Dang et al. (2023).

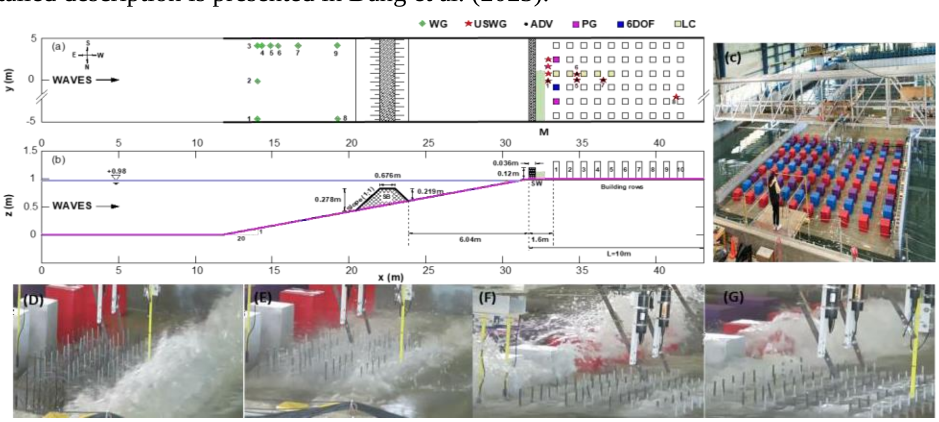

Figure 1 – Plan view and profile view of experimental bathymetry and instrumentation setup

Several configurations were investigated to investigate their effectiveness, including baseline (absence of mitigation), submerged breakwater-only (SB), seawall-only (SW), combined a seawall and a submerged breakwater (SWSB); mangrove forests arranged in four rows (4M), and eight rows (8M). Specifically, Figures 1D~1G show the visual snapshots of the broken tsunami-like wave (A = 0.21m, d = 0.98m) interacting with the mangroves (8M). The tsunami-like wave initially interacted with the mangrove forest as a broken wave, which was attenuated by mangroves, then impinged on the front face of the building rows and subsequently collapsed and moved in the offshore direction.

Numerical simulations based on the olaFlow solver (Higuera et al., 2015), derived from the OpenFOAM platform, were implemented to comprehensively investigate the flow patterns around the building elements that were not fully clarified through the physical experiments. The olaFlow solver can solve RANS equations using the FVM method and employs the VOF technique to track the free surface displacement. Figure 2 shows a comparison of measured and simulated time series of horizontal forces in the first building row (blue and yellow squares in Figure 1a). Generally, the olaFlow model effectively replicates the measured time series of forces with a maximum difference of less than 8%.

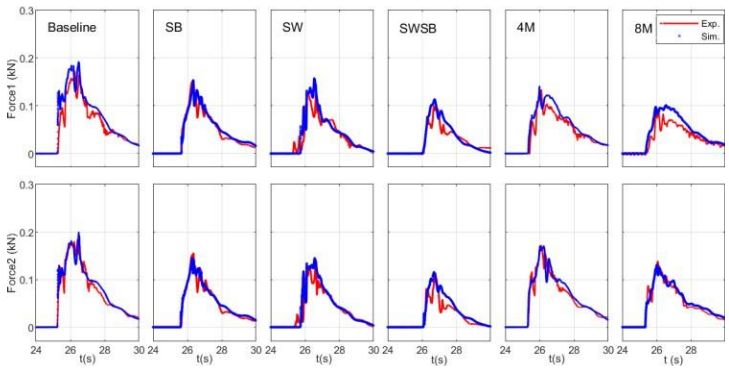

Figure 2 – Comparisons of measured and simulated force in the first building row under wave case (A = 0.21 m, d = 0.98 m)

3 PRELIMINARY RESULTS

The preliminary numerical results exhibit good agreement with the experimental results; therefore, the olaFlow model was utilized to further investigate the flow patterns in building elements. Figure 3 shows the hydrodynamic pressure distribution at the front face of building elements in the first row at specific time instants when their maximum forces occurred. Specifically, for mangrove configurations, two building elements, fully sheltered and partially sheltered by mangroves in the most seaward row, are tested for comparison with grey configurations. At these time instants, there are little differences in wave runup heights measured at Baseline, SB, SW, partial shelter by 4M and by 8M conditions, equal to 1.5 times greater than those in the SWSB and fully covered by 4M and 8M scenarios. Generally, the presence of mitigation structures effectively reduced baseline hydrodynamic pressures. A slight difference in both wave runup and hydrodynamic pressures in SWSB and full shelter by 8M was observed. Figure 3K shows the variation of maximum force distribution in the first five building rows. A maximum force in SB, SW, full shelter by 4M, and partial shelter by 8M show a similar pattern, exhibiting 23% baseline force reduction. Moreover, the maximum force of SWSB in the first row reduces approximately 50% of the baseline force, marginally exceeding 4% of the performance of buildings fully sheltered by 8M configuration. The preliminary results further imply the potential implementation of green structures in protecting coastal communities against extreme coastal flooding.

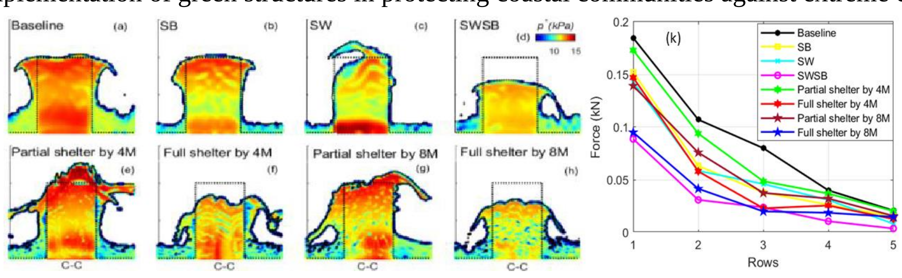

Figure 3 – Hydrodynamic pressure distribution in the front face of the first building row over eight configurations (left) at the time of maximum force and variations of maximum forces over five building rows at different configuration (right)

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