EXPERIMENTAL MODELING OF WAVE FORCES AND HYDRODYNAMICS ON ELEVATED COASTAL STRUCTURES SUBJECT TO WAVES, SURGE OR TSUNAMIS: THE EFFECT OF BREAKING, SHIELDING AND DEBRIS

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BACKGROUND

Coastal communities provide important economic, transport, and recreational services to large numbers of people worldwide. However, these coastal communities are vulnerable to damage by extreme events such as tropical cyclones or tsunamis. Waves and surge, as well as tsunami-wave events, may cause extensive damage to elevated structures through a combination of horizontal and vertical wave and surge-induced forces. Structural elevation has been shown to be a critical variable affecting damage and loss. Recent efforts have been made to retrofit structures or improve coastal protection and damage mitigation plans in coastal communities to increase community resilience. However, to effectively retrofit old structures or design new structures to resist damage due to hurricanes or tsunamis, engineers require an accurate estimation of both the wave hydrodynamics and the resulting loads.

Several theoretical, empirical, numerical, and experimental studies provide different procedures to estimate the pressure distribution and wave-induced loads on coastal structures, e.g. seawalls, vertical cylinders, platforms, bridges, piers, jetties, and crown walls. In these studies, the relevant effect on the type of breaking, as well as wave type, is thoroughly analyzed, although in several occasions over-simplified. Moreover, the effect of relative structure elevation, three-dimensional (3D) flow alteration, as well as waterborne debris, remain largely unexplored.

This study describes an extensive series of large-scale experiments to create a comprehensive dataset to derive horizontal and vertical wave forces on elevated coastal structures subject to the variability of storm waves, surge, and tsunamis, incorporating the effect of the relative structure elevation (air-gap), breaking type (non-breaking, breaking, or broken), 3D flow alteration due to near-structure shielding, and waterborne debris. Papers already published (Park et al., 2017) and under preparation include a detailed description of the experimental procedures, model layout, instrumentation and dataset characteristics. The work also include the description of the different wave and water level conditions tested, and the uncertainty analysis of the results via repeatability tests.

LABORATORY EXPERIMENTS

Large-scale experiments in Oregon State University's Large Wave Flume (LWF) collected benchmark data to measure surface elevation (wave heights), pressures, loads, and 3D velocities for regular, irregular, solitary, and transient waves. The flume measures 104 m long, 3.66 m wide, and 4.6 m deep, with adjustable bathymetry. The piston-type wave maker assembly can generate regular, irregular, and tsunami-type waves and is equipped with active wave absorption system for large reflected waves. The test specimen consisted on a rigid steel box (1 m x 1 m x 0.6 m) supported by a frame (Figure 1) and fully instrumented with axial load cells, multi-axial accelerometers, and pressure transducers.

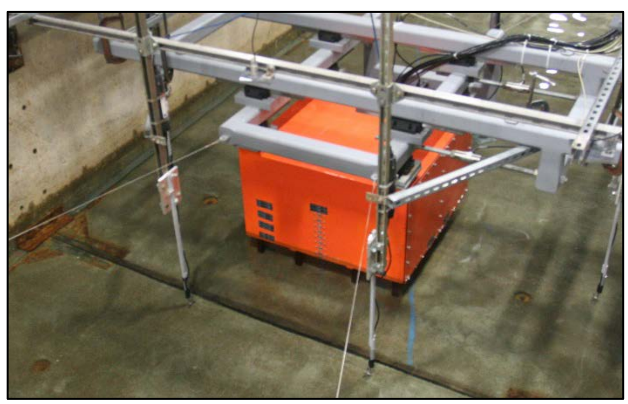

Figure 1 – Test specimen of an elevated coastal structure during the experiments in the Large Wave Flume at OSU.

The profile of the bathymetry deployed along the flume consisted of a flat offshore section 14.3 m long, followed by a 26.15 m long foreshore compound slope starting with a steeper section at 1:12, then a milder 1:24 slope, and ending at an elevated flat beach section, 36.03 m long and 1.75 m above the flume floor. The test specimen was placed 0.25 m onshore from the start of the elevated flat section. The bathymetry profile ended on a 7.52 m long, 1:12 slope for wave dissipation (Figure 2).

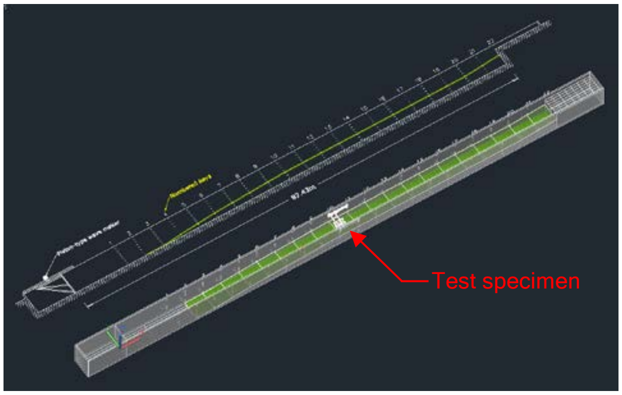

Figure 2 – CAD rendering of the Large Wave Flume at Oregon State University with the piece-wise bathymetry cross-section (green), and location of the test specimen (orange).

TEST PROGRAM

The full experimental campaign consisted in three phases:

I) Effect of surge elevation and air-gap for storm (hurricane) and transient waves on an elevated coastal structure with no support columns (Park et al., 2017).
II) Effect of shielding structures and 3D induced flow for transient and solitary wave conditions on a fixed elevated coastal structure with columns.
III) Effect of waterborne debris with transient and solitary wave conditions on a fixed elevated coastal structure with columns.

Figure 3 presents a series of selected images of the experiments carried out during the 3 phases. Overall, more than 1,080 tests have been carried out, including structural characterization tests (i.e. pluck, hammer and swing tests), wave calibration tests in undisturbed conditions (no specimen), as well as regular, random, and tsunami-wave tests. The test program also considered the effect of non-breaking, breaking and broken waves, as well as a comprehensive repeatability series for uncertainty analysis.

INSTRUMENTATION AND DATABASE

Along the different test phases, the surface elevation was measured at up to 9 locations along the flume with resistive and acoustic gauges to define wave conditions at the offshore and nearshore locations, as well as around the specimen to characterize the overland flow. Acoustic Doppler Velocimeters were deployed at 7 locations, while 9 submersible axial load cells were used to capture the hydrodynamic forces acting upon the specimen (including 2 load cells installed to measure the forces on the supporting legs). Additionally, 5 tri-axial accelerometers were also installed inside the specimen at selected locations as part of the characterization efforts of the structure, and finally, 14 pressure transducers were placed at any given time in up to 31 different possible locations.

The database has been uploaded in DesignSafe CiberInfrastructure, part of the NHERI Program, for further analysis, publication and public availability.

Figure 3 – Test specimen of an elevated coastal structure during the experiments in the Large Wave Flume at OSU.

ACKNOWLEDGEMENTS

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REFERENCES

Park, Tomiczek, Cox, van de Lindt, Lomonaco (2017): Experimental modeling of horizontal and vertical wave forces on an elevated coastal structure, *Coastal Engineering*, vol. 128, pp. 58-74.