Wave Forces on Coastal Protection Model Shutters used against Storm Surge

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Abstract

In this study the effect of wave forces and impact pressures during a storm surge on vertical model shutters, used to protect the coastline were investigated. Laboratory experiments were conducted to determine the wave forces and impact pressures on vertical shutter in a wave tank. Numerical simulation, using computational fluid dynamics (CFD) results were comparable to the experimental results.

1. Introduction

A storm surge is primarily caused by the extremely high winds which accompany a hurricane. This wind pushes the water rapidly, building it up into a huge wave. At the same time, the low pressure caused by a hurricane also causes the water level to rise up in the lowest-pressure spots and to sink in areas of higher pressure, exacerbating the wave buildup caused by the winds. Additionally, the shape of the ocean floor may affect how high the waves of the storm surge are when they reach land. It is not uncommon to see a storm surge in excess of 18 feet (6m), a wave that can potentially cause dramatic damage. The largest recorded storm surge was in Australia in 1899, where the storm surge reached heights of 43 feet (13m). In the United States in 2005, storm surges associated with Hurricane Katrina reached 30 feet (9m). When a wave breaks directly on a vertical faced coastal structure, impact pressures are produced which can be extremely high in magnitude and short in duration. Some investigators (Carr, 1954) have pointed out that the rarely occurring extreme wave impact pressures and the resulting forces of very short duration are unlikely to be of serious consequence in designing a structure against sliding and overturning. The investigation of the dynamic behavior of the vertical walls under the wave impact load does not seem to have received much attention.

2. Objective

The objective of this study was to verify the wave forces (experimentally and numerically) on a vertical model shutter used in developing coastal protection system to protect against storm surge.

3. Analyses

For experimental study a wave tank was constructed with dimensions of 5 ft. x 1.5 ft. x 1.5 ft. (L, B, and H). A flap type wave generator was used for making the waves, the wave heights at different locations are measured using wave gauges, and maximum wave height obtained in the model was 1 ft. For measuring wave impact pressures on the vertical model wall of a plate of dimensions 1.5 ft.(width) x 1.1 ft.(height) x 0.0416 ft.(thickness) made of Plexiglas shutter was fixed at a distance of 1.5 feet from the wave maker to make sure that the wave impact pressure was maximum on the plate, the lower end of the plate was fixed to the wave tank and the sides of the plate sealed with silica gel to prevent leakage. Four strain gauges are attached to the plate; from the measured strains the maximum displacement occurred in the plate was calculated. Numerical simulation was done using commercially available software COMSOL using the finite element approach; the theory behind the software is using the incompressible navier-strokes equations for fluid domain and solid domain (structural deformation) was solved using elastic formulation and non-linear geometry formulation. The numerical simulation was optimized using mesh sensitivity analysis.

4. Discussions

The displacements measured for the plate were minimum at the bottom and maximum at the top. In the numerical simulation the plate was replaced by different types of materials such as concrete, steel and wood. The maximum displacement occurred in wood and minimum in steel, the impact pressure was the same for all three materials maximum at the bottom and minimum at the top. The variation of maximum pressure and displacement with shutter height are shown in Fig. 1. The results showed that the wave impact pressure increased as the height of the plate increases. Similarly the displacement increased with the increase in shutter height.

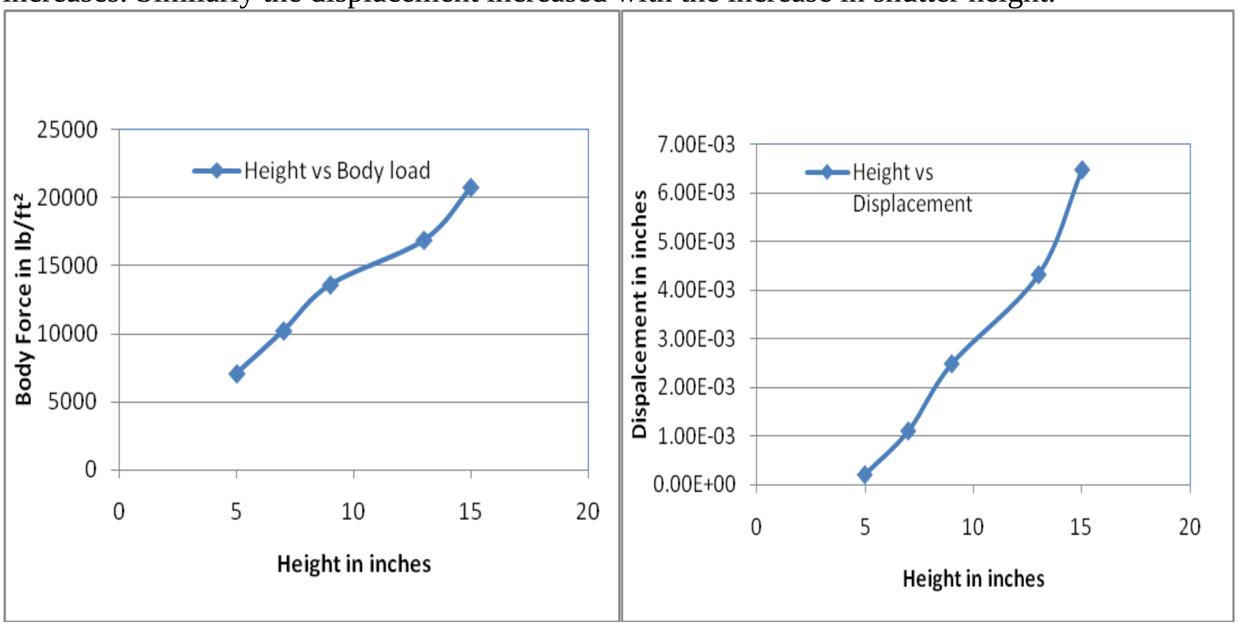

Fig. 1. Variation with shutter Height (a) Maximum pressure and (b) Maximim Displacement.

5. Conclusions

Based on the experimental results and numerical simulation the impact pressure and maximum displacement on the model shutter plate has been quantified.

6. Acknowledgement

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7. References

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