

## **Void Fraction in Green Water**

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### **ABSTRACT**

The present study investigates the void fraction as well as velocity of an overtopping flow on a structure through laboratory measurements. The overtopping green water was generated by the impingement of a plunging breaking wave on the structure. The flow is multi-phased and turbulent with significant aeration. In this study, fiber optic reflectometer and bubble image velocimetry were employed to measure the void fraction and velocity in the flow, respectively. Various mean properties were obtained by ensemble-, time-, and depth-averaging the repeated instantaneous measurements. The temporal and spatial variations of void fraction reveal very high aeration near the front of green water and relatively low aeration in the region near the deck surface. Using the measured data, a similarity profile was obtained for the depth-averaged green water void fraction on top of the structure. The void fraction profile suggests that using only velocity data may be insufficient if the flow momentum is to be estimated. The accuracy of the void fraction measurement was validated by comparing the directly measured water volume of the overtopping flow with the calculated water volume from the measured velocity and void fraction.

**KEY WORDS:** Green water; void fraction; fiber optic reflectometer; offshore structure.

### **INTRODUCTION**

The impingement of a large breaking wave on an offshore structure is of great concern to the safety of the offshore structure. Tremendous green water loads were estimated during such an impact and were found to be responsible to the damages of structure during large storms. Green water loads occur when an incoming wave significantly exceeds the free board and water rushes onto the deck. In order to understand

the process, both the velocity and the void fraction fields are needed. However, not only is green water very difficult to measure in the laboratory and field, it is also very difficult to simulate numerically.

Breaking waves have a multiphase and turbulent nature. If a wave breaking event takes place near a structure, aeration and turbulence becomes even more complicate. Most laboratory measurements of wave breaking or green water were taken outside the aerated region because of the incapability of the available measurement tools used (e.g., Chang and Liu, 1999; Cox and Ortega, 2002). Ryu *et al.* (2005) recently introduced a technique called bubble image velocimetry (BIV) for measuring the velocity field in bubbly flows. They used the technique to obtain the velocity in the vicinity of a structure impinged by a breaking wave. They utilized imaging methods and correlated the texture in the flows for velocity determination and opened a door for possible full-field velocity measurements in highly aerated flows such as breaking waves and wave impingement and green water. Unlike velocity measurements, there have been relatively a large number of studies on void fraction of breaking waves in the aerated region, although reports relating to void fraction in green water flows are rare.

This study presents investigation the void fraction measurements of an overtopping green water flow on top of a structure by breaking waves. Void fraction was measured with fiber optic reflectometer (FOR) introduced by Chang *et al.* (2003). The velocity measurements, performed using the BIV method (Ryu *et al.*, 2005). Repeated instantaneous measurements of void fraction were ensemble-averaged to obtain mean properties. Using the measured velocities and void fraction, the flow rate and water volume of the overtopping water were estimated. Empirical self-similarity equations, based on similarity laws, of depth-averaged void fraction, depth-averaged velocity, and overtopping water level were obtained by applying dimensional analysis and regression of the measurement data.