

Estimation of Collision Force of a Drifted Container Due to Run-up Tsunami

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ABSTRACT

In this study, characteristics of the run-up tsunami and behavior of drifted container are discussed based on laboratory and numerical experiments. Also, effectiveness of the vertical wall, which is installed in order to reduce damages due to tsunami, is investigated. This paper proposes empirical formula to evaluate wave force due to run-up tsunami considering the added mass, based on momentum theorem, and its validity is discussed. Moreover, the nonlinear finite element collision model, LS-DYNA3D, is used to estimate the collision time to determine the volume of the added mass. Through these discussions, validity of the numerical model and necessity of considering the added mass are confirmed. Furthermore, it is revealed that the velocity of the collision and the weight of the container are important parameters in estimating the collision force.

KEY WORDS: Tsunami; drifted container; collision force; added mass; LS-DYNA3D

INTRODUCTION

Recently, human and property damages due to tsunamis by ocean trench earthquakes such as Java earthquake have been reported. In severe tsunami events, the direct damages are caused by run-up tsunami waves. In addition, not only such direct damages due to tsunami waves but also indirect damages caused by drifted vessels, automobiles and debris of destroyed houses and other facilities are also reported (e.g., Tatsumi et al., 2007). Countries bordering oceans with trenches like Japan should prepare countermeasures against both direct and indirect damages caused by tsunamis. Particularly, damages in ports may affect economic activities significantly not only in damaged country but also in other countries with economic relations. Thus, the effect of the tsunami on ports should be discussed and its countermeasures should be prepared. In this study, the behavior of container due to tsunami is focused and damages due to collision of a drifted container with a backyard-structure are discussed.

Regarding the behavior of drifted body due to tsunami and its collision force, Ikeno et al. (2001) investigated the behaviors of the drifting timber and the collision forces of the drifting timber on the vertical seawall. It is pointed out that collision force can be obtained if the momentum of a drifting body is identical, regardless of shapes of the drifting body. Moreover, Ikeno et al. (2003) discussed the collision forces of the drifted timbers due to run-up tsunami on the land. From these results, the wave force due to run-up tsunami is found to be larger than that due to non run-up tsunami. Haehnel et al. (2004) conducted

the laboratory experiments to estimate the maximum collision force of the woody debris on the structures in floodplain. They examined existing three representative approaches to estimate the maximum impact force, and found that all approaches can be summarized in one model which expressed in terms of the mass of the colliding body and collision velocity.

Among of related studies, Mizutani et al. (2005, 2006) pointed out the water mass (added mass) behind of the drifted container play important roles on the collision, and proposed a formula to estimate the collision force due to a drifted container considering the effect of the added mass behind the container. The volume of the added mass, however, is a function of the collision time, which is hard to evaluate by the laboratory model experiment. In this study, therefore, the collision time and force are estimated by the full scale numerical collision simulation using LS-DYNA3D, considering the added mass for a case that the container collides with a concrete pier. The weight of container, velocity of drifted container just before a collision, added mass and stiffness of collided body are considered to affect the collision time and force, and these effects are discussed in this paper. In accurate estimation of the collision time, a concept of the vehicle collision analysis (Itoh et al., 1998) is introduced and simulations with variations container's size and collision's direction are conducted.

Moreover, the effect of vertical wall installed at the leading edge of apron is investigated as a countermeasure for the damage reduction of the tsunami. This paper examines the effectiveness of this vertical wall in relation to the run-up wave height, fluid velocity on the apron, velocity of the drifted container, and collision force.

HYDROULIC MODEL EXPERIMENT

Experimental Condition

To investigate characteristics of the run-up tsunami and behavior of drifted container, laboratory model experiments were carried out using a wave tank (30.0m in length, 0.7m in width and 0.9m in depth) of Nagoya University, as shown in Fig. 1. Sloping bottom (slope 1:10 and 1:100) and rectangular apron (2.0m long, 0.7m wide and 0.48m high) modeled in scale of 1/75 were installed in the wave tank. Long period waves and solitary waves were generated by a piston type wave generator, whose maximum stroke is 1.5m. Details of waves generated and water depth conditions are listed in Table 1. In the experiment, 20 and 40ft container models whose weights were ranging from 0.15 to 1.3N were used in the experiments, then the behavior of each container and the collision force were investigated.