Impact Force of Flood-Borne Vehicles

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INTRODUCTION

Tsunami, hurricane storm surge, and waves generate debris such as shipping containers, wood logs, and vehicles. Impact forces exerted on structures in the inundation zone by such debris might result in severe structural damage of structures. Thus, reliable prediction of debris impact force is essential for the safe design and risk assessment of structures in the inundation zone. In this study, we carried out full-scale air-borne and flood-borne vehicle impact experiments. The experimental results enable characterization of the vehicle impact and prove the applicability of a theoretical equation (Haehnel and Daly, (2004)) in which the impact force of debris is estimated by using the impact velocity, axial stiffness, and mass of the debris. In addition, by analyzing NHTSA (National Highway Traffic Safety Administration)'s experimental data, a list of axial stiffness for various types of vehicles was constructed, which is important in predicting the flood-borne vehicle impact force.

EXPERIMENTS

The vehicle used in the experiments had the following characteristics: 3.3 m length, 1.4 m width, 1.5 m height, and 316 kg weight. In the flood-borne experiment, a tsunami-like bore was generated by rapidly opening the gate installed upstream of the test section. The vehicle set on the test section was drifted by the bore and made to collide with a vertical plate that can measure the impact force (Figure 1). Velocity and depth of the flow and impact speed of the vehicle were also measured.

EXPERIMENTAL RESULTS

Figure 1 shows the relationship between the impact speed and impact force measured in the flood-borne and air-borne vehicle impact experiment. The line in Figure 1 is obtained by regression analysis of the experimental result denoted by dots in Figure 1. Haehnel and Daly (2004) showed that the impact force of debris is the product of the impact speed of debris and square root of the product of the stiffness and mass of debris. Therefore, the axial stiffness of the vehicle is determined for each line, and the axial stiffness of the vehicle is represented by the slope of each line in Figure 1. According to Figure 1, the slope of the line depends significantly on the impact speed of the vehicle. In other words, the axial stiffness of the vehicle varies nonlinearly depending on the impact speed of the vehicle. As shown in Figure 1, the impact force of the vehicle can be estimated by using the estimation equation proposed by Haehnel and Daly (2004) if appropriate axial stiffness of the vehicle corresponding to the impact speed of the vehicle is given. However, data on the stiffness of various types of flood-borne vehicles is limited. Thus, a list of stiffness values for various types of vehicles would be useful for estimating the flood-borne vehicle impact force.

THE STIFFNESS OF VARIOUS TYPES OF VEHICLES

NHTSA has been conducting experiments on vehicle impact against a vertical rigid wall. Experimental data (time series of the axial impact force, acceleration of the vehicle, etc.) are available on the NHTSA's web page. By performing second-order integration on the acceleration of the vehicle, the time series of the displacement of the vehicle can be obtained. Using this procedure, the relationship between the impact force and displacement can be obtained for various types of vehicles such as sedan, pickup truck, and so on. Examples of such relationships are shown in Figure 2. Although the impact speed is almost similar in each experiment, significant difference is seen depending on the type of vehicle. According to Figure 2, stiffness of the pickup truck is approximately 200%-300% higher than that of the sedan. Thus, the stiffness of the vehicle is found to vary, not only with the impact velocity as mentioned previously, but also with the type of vehicle. By analyzing NHTSA's experimental data, a dataset related to the stiffness of various types of vehicles corresponding to the impact speed of flood-borne vehicles is developed.

REFERENCES

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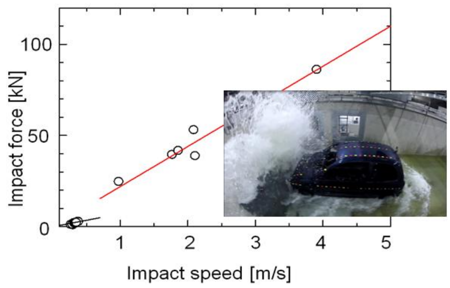

Figure 1 – Relationship between the impact speed and impact force. Dots represent experimental results, while the line indicates prediction according to the estimation equation proposed by Haehnel and Daly (2004). The red and black lines represent flood-borne and air-borne experiments, respectively.

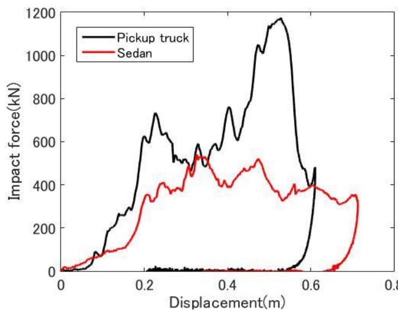

Figure 2 – Relationship between the impact force and displacement of two types of vehicles obtained by analyzing the NHTSA's experimental data.