Characteristics of Tsunami Fluid Force Acting on Girder Bridge

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ABSTRACT

The horizontal and vertical components of tsunami fluid force acting on a girder bridge are measured in hydraulic experiments. The wave pressure on the model bridge is also measured. The vertical impact force is estimated by the change in the added mass of the model bridge. The relationship between the normalized maximum wave pressure and the normalized tsunami height above the bridge is also illustrated.

KEY WORDS: Fluid force; impact force; girder bridge; added mass.

INTRODUCTION

It has been pointed out that large scale earthquakes will occur near Japan and the tsunamis caused by the earthquakes will strike coasts of Japan. In many coastal regions in Japan, mountains are very close to the sea and main roads have been constructed along the coast line. If a bridge on the main road across river is washed away by tsunami, it is difficult to set up the diversion in several cases because of mountainous area. However, tsunami fluid force has not been taken into account in the present design of bridges. Therefore, the stability of bridges and the countermeasures to prevent bridge from being washed away have to be investigated.

The characteristics of tsunami fluid force acting on coastal and harbor structures have been investigated by many researchers. Matsutomi (1991), Asakura et al. (2000) and Mizutani and Imamura (2000) measured the wave force or the wave pressure acting on coastal structures due to tsunami. Asakura et al. (2000) also proposed the equation for estimating the fluid force acting on structures constructed behind seawalls due to overflowing tsunami on the basis of the experimental results. Ikono et al. (2005) measured the wave pressure due to tsunami with soliton fission acting on vertical breakwaters. Mizutani et al. (2006) measured the tsunami fluid force acting on containers on aprons on a harbor.

The characteristics of tsunami fluid force acting on bridges are different from that acting on breakwaters and vertical walls because there is a clearance between the structures and the water surface. The researches on tsunami fluid force acting on bridges have been conducted since Indian Ocean Tsunami 2004. Honma et al. (2005) investigated the damage mechanism of Omori Bridge in Hokkaido, Japan caused by wind waves through the model tests in which fluid force acting on the bridge was measured. Kataoka et al. (2006) verified that the Goda’s formula did not underestimate the measured tsunami fluid force acting on a bridge. However, the characteristics of the tsunami fluid force were not investigated sufficiently. Shoji et al. (2009) investigated the sliding of a bridge beam caused by tsunami. However, the vertical component of the tsunami fluid force acting on the bridge was also not investigated sufficiently. Although Araki and Deguchi (2009) investigated the fluid force acting on bridges, the shape of the cross section of the bridge beam was simplified. The aim of this study is to investigate the characteristics of the tsunami fluid force acting on girder bridges and to try to estimate impact force acting on the bridge.

EXPERIMENTAL SET-UP

Hydraulic experiments were conducted in a two-dimensional wave flume which is 41.0m long and 0.7m wide in Osaka University. Figure 1 shows a rough sketch of the experimental set-up. The bottom slopes of the sea and the river were 1/40 and 1/100, respectively. The incident wave which has a long wave period, e.g., 10s, was generated by piston type wave generator. The tsunami height \( a \) was defined as the maximum rise in the water surface as shown in Figure 2. The directions of the horizontal and the vertical fluid forces \( F_x \) and \( F_z \) are also illustrated in Figure 2. In this experiment, the tsunami height in front of the model bridge was ranged from 7.8 cm to 14.2 cm. Table 1 shows the still water depth at the model bridge \( h \) and the clearance under the bridge \( hc \) used in the experiments.

Figure 3 illustrates the model bridge. The model bridge has three main girders. Figure 4 is a photograph of the reverse side of the model bridge. The reverse side of the model bridge is like a grid. The horizontal and vertical components of the tsunami fluid force acting on the model bridge were measured by force transducer. Figure 5 is a photograph of the model bridge installed in the wave flume. The wave pressure on the model bridge was also measured at four points from P1 to P4 shown in