EXPERIMENT FOR TSUNAMI VERTICAL FORCE ON BRIDGE GIRDER

Graduate School of Kyushu Institute of Technology Student Member ○Li Fu
Kyushu Institute of Technology Regular Member Kenji Kosa
Chodai Co., Ltd. Regular Member Takashi Sato
Nippon Engineering Consultants Co., Ltd. Regular Member Tatsuo Sasaki

1. INTRODUCTION

Great East Japan Earthquake occurred on March 11th 2011, and caused a lot of bridge girders flowing out in Tohoku Area. After earthquake, the authors analyzed a lot of videos and photos recording tsunamis at some seriously damaged areas such as Rikuzentakata, and found that generally the tsunami wave that affected bridge girder showed a condition of steady flow, the water level rise of which was relatively slow (1~2[m/min]). Therefore, the experiment for steady flow was conducted to study the wave vertical force (called vertical force) on concrete bridge girder.

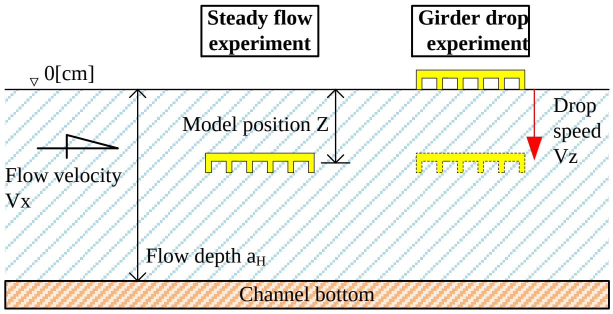
2. STEADY FLOW EXPERIMENT

As shown in Fig. 1, with a scale of 1/50, a girder model was made and six pressure meters (P8~P13) were installed on the model. Based on the Froude number, two types of experiments were considered. First was the steady flow experiment and model position Z was considered as the main parameter. In the 100[cm/s] (prototype: 7.1[m/s]) steady flow, the case of Z=-7[cm] was set as standard case. Second was the girder drop experiment to simulate the phenomenon of water level rise of steady flow and the model was dropped with a speed of Vz=90[cm/min] (prototype: 6.3[m/min]).

The facilities of experiment are illustrated in Fig. 2. With the use of a pump, steady flow was created. Three velocity meters, six wave gauges were set along the water channel. Wave force on the model was measured by a force transducer T, the setting image of which can be seen in Fig. 5.

First, the result of standard case of steady flow experiment was introduced. As shown in Fig. 3, vertical force $Fz_{(T)}$ measured by T exhibited a variation of stable condition, thus the average force was used for evaluation, which was -16.8[N] (minus means downward). Besides, vertical force $Fz_{(P)}$ was also obtained by the integration of forces calculated by pressure results from P8~P13, and the calculated force (-16.3[N]) agreed with the measurement very well.

As illustrated in Fig. 4, it was noted that the average pressures on both model top and bottom were downward, and the



Steady flow

a_H [cm]	Vx [cm/s]	Z [cm]
35	100	-7 (standard)
		-14
		-21
		-28

Girder drop

a_H [cm]	Vx [cm/s]	Vz [cm/min]
35	100	90

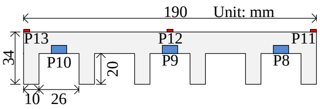


Fig. 1 Experimental Cases and Girder Model

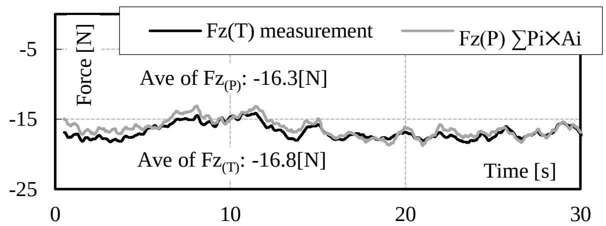


Fig. 3 Vertical Force (Sta. Case)

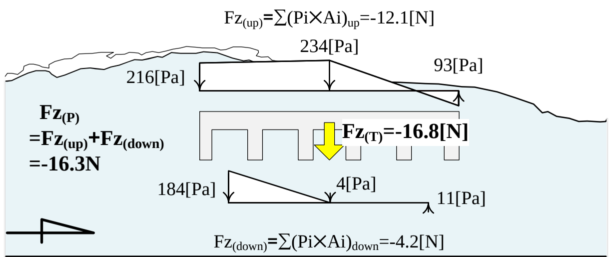


Fig. 4 Pressure Results (Sta. Case)

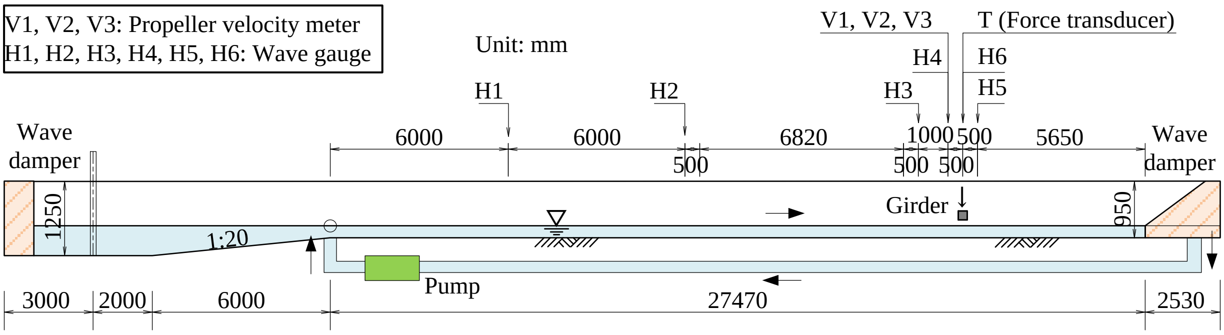


Fig. 2 Experimental Facility

Keywords: Wave vertical force, Bridge girder, Steady flow experiment, Girder drop experiment
Contact address: 〒804-8550 Kyushu Institute of Technology, Tobata, Kitakyushu, Tel: 093-884-3123

downward effect on model top caused by overflow effect was considered as the main reason of downward vertical force.

After that, as shown in Fig. 5, the vertical force $Fz'_{(T)}$ (-31.9[N]) caused by steady flow was obtained by eliminating the buoyancy effect U with the use of the equation: $Fz'_{(T)}=Fz_{(T)}-U$.

3. GIRDER DROP EXPERIMENT

After that, the result of girder drop experiment was introduced. As shown in Fig. 6, the vertical force variations of $Fz_{(T)}$ measurement and $Fz_{(P)}$ calculation by pressure results showed a similar trend: after dropped into steady flow, downward $Fz_{(T)}$ first affected and then since t=12[s], force $Fz_{(T)}$ turned to upward and then increased to the maximum. In order to obtain the vertical force $Fz'_{(T)}$ caused by steady flow, the model drop procedure was conducted in a condition of static water with a speed of Vz=90[cm/min] to estimate the variation of buoyancy effect. Consequently, it was observed that buoyancy increased gradually while model was just dropped into flow and then kept as a constant about 17.2[N]. Afterwards, the variation of vertical force $Fz'_{(T)}$ caused by steady flow was obtained by the difference between $Fz_{(T)}$ and U. As a consequence, until t=20[s] downward force kept affecting on the model and after that time point, upward force occurred and increased to the maximum 5.8[N] at 22.183[s], when the model was dropped to Z=-26[cm].

In Fig. 7, the pressure distribution when the model was lowered to Z=-7[cm] (t=9.800s) was plotted as a representative of the stage, in which great downward force $Fz'_{(T)}$ happened. As a consequence, it is observed that the wave pressures on the model top and bottom showed same level. And once eliminating the buoyancy effect, a great downward force $Fz'_{(T)}$=-20.3[N], which was the force caused by steady flow, was obtained.

In Fig. 8, the pressure distribution when the maximum uplift force $Fz'_{(T1)}$=5.8[N] happened was plotted. In that condition, the average pressure on the model bottom (2052[Pa]) was confirmed 200[Pa] greater than that on the model top (1852[Pa]). Therefore, even eliminating the buoyancy effect, $Fz'_{(T)}$=5.8[N] uplift force was obtained, and this was considered as the uplift effect caused by steady flow besides the buoyancy effect.

At last, the comparison of vertical forces $Fz'_{(T)}$ of two types of experiments at the typical model positions Z=-7, -14, -21, -28cm is plotted in Fig. 9. It is obvious that for all cases of steady flow experiment, only downward forces were obtained. On the other hand, for the girder drop experiment, after the model was lowered to the center of flow, uplift force occurred. And the maximum uplift force was obtained as 5.8[N], when the model was lowered to Z=-26[cm]. That is, besides buoyancy effect, 5.8[N] (about 40% of buoyancy effect) uplift force affected on the model.

4. CONCLUSIONS

From the experimental results of steady flow experiment and girder drop experiment, the following conclusions are summarized:

(1) In the standard case of steady flow experiment, due to overflow effect, a relatively bigger downward pressure caused a downward vertical force $Fz'_{(T)}$ on the model.

(2) For the steady flow experiment (Vx=100[cm/s]), only downward vertical force $Fz'_{(T)}$ was found for all cases.

(3) For the girder drop experiment, different from steady flow experiment, uplift vertical force $Fz'_{(T)}$ was found when the model was dropped to the center of flow and the maximum uplift force $Fz'_{(T)}$ was confirmed as 5.8[N], which was about 40% of the buoyancy effect on the model.

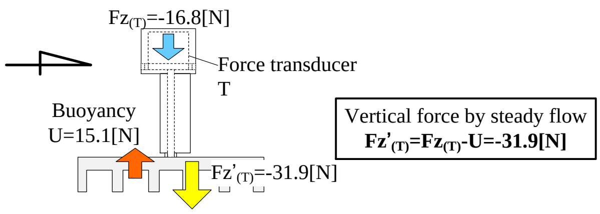


Fig. 5 Vertical Force (U Eliminated, Sta. Case)

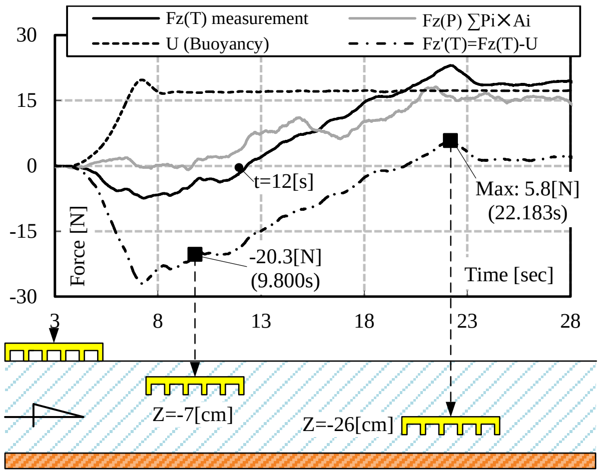


Fig. 6 Vertical Force (Girder Drop)

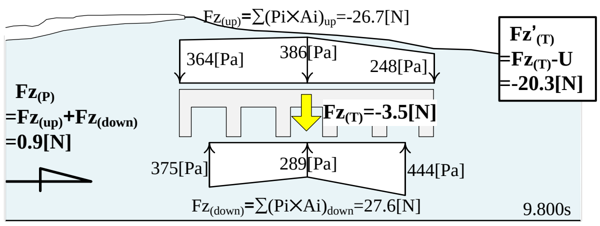


Fig. 7 Pressures (Girder Drop, Z=-7[cm])

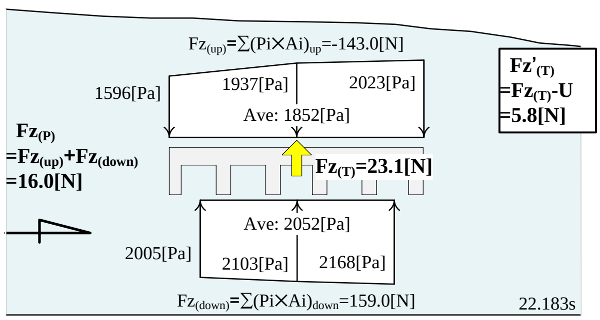


Fig. 8 Pressures (Girder Drop, Z=-26[cm])

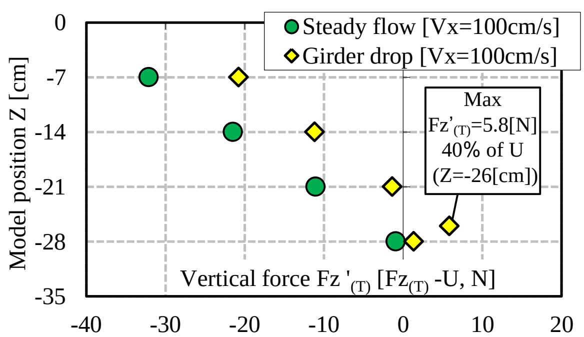


Fig. 9 Vertical Force (U Eliminated)