EXPERIMENT FOR COMPARISON OF TSUNAMI FORCES ON BRIDGE

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

1. INTRODUCTION

Great East Japan Earthquake occurred on March 11th 2011, and caused a destructive tsunami to Tohoku Area. After earthquake, the authors carried out a field survey to Tohoku Area and found that a lot of coastal bridges were washed away by tsunami. Besides, generally the tsunami wave shape is confirmed as "steady flow with bore wave" (called steady flow in the following). The experiment for steady flow has been conducted, and the comparison of wave horizontal forces (called wave force in the following) by measurement and calculation is studied.

Fig. 1 Tsunami of Steady Flow Type

2. TSUNAMI EXPERIMENT

2.1 Objective wave types

After great tsunami damage, the available videos recording tsunami were collected and analyzed. From the video, it is noted that for most damaged areas, the tsunami wave shape likes steady flow as shown in Fig. 1, which plots the tsunami attacking on Aneha Bridge in Rikuzentakata City. Therefore, the experiment of steady flow was conducted to study wave forces on bridge girder.

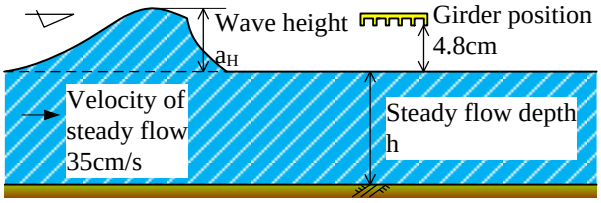

Fig. 3 Image and Parameters of Steady Flow

2.2 Experimental facility and parameters

The facilities of experiment are illustrated in Fig. 2. With the use of pump, the steady flow can be kept with a fixed velocity and afterwards the bore wave can be created by the wave making plate. Three velocity meters, six wave gauges and one force transducer were set along the water channel. The velocity meter V2 was set right ahead of girder model while the velocity meter V3 was set at the water surface of steady flow (Fig. 8).

As shown in Fig. 3, in the experiment, the steady flow velocity is kept as 35cm/s while the bridge girder position is fixed as 4.8cm above steady flow surface. On the other hand, three series of cases (steady flow depth h=25cm, 35cm, 50cm) were conducted with wave heights as parameters.

3. EXPERIMENTAL RESULT

By taking the case (h=25cm, a_H=17cm) as a sample, the experimental results are described in this chapter. Firstly, as plotted in Fig. 4, the time cell of original output of wave force variation is

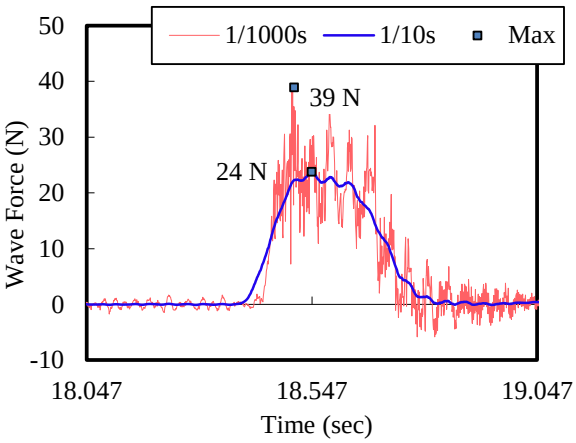

Fig. 4 Wave Force Variation

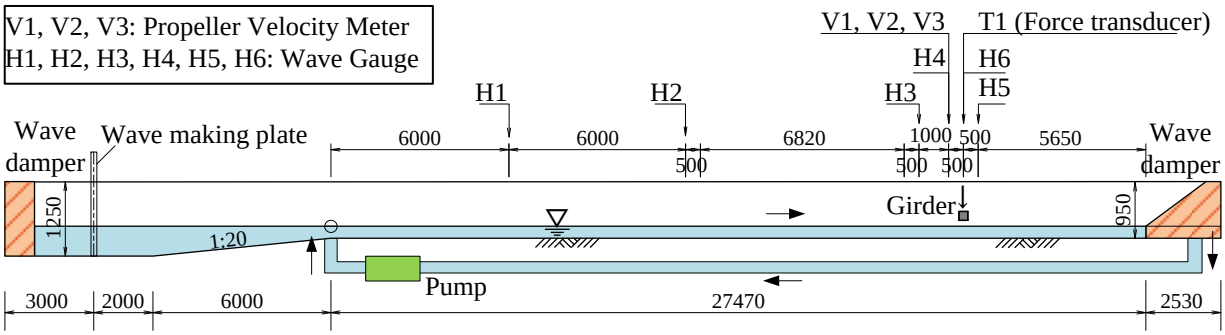

Fig. 2 Experimental Facility

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

0.001s and the obviously great volatility due to resonance with experimental facility is observed. Thus, in order to eliminate the volatility, the 0.1s smoothing of original data was carried out and after smoothing, the volatility disappeared. The peak value of force is 24 N, which is regarded as maximum force on girder.

The result from H4 is applied to evaluate wave height. By the same method, as shown in Fig. 5, after smoothing the peak value is 17.37cm, and there is no significant change compared with original 19.05cm. From the wave height variation, it is obvious that the bore wave did not break near bridge girder model.

Similarly, as shown in Fig.6, the wave velocity variations from V2 and V3 are drawn and for both of them, the peak values after smoothing almost did not change compared with original data. Besides, it is observed that compared with of V2 (129cm/s), the peak value of V3 (120cm/s) is smaller. Thus, it is concluded that at different positions of wave, the wave velocity changes.

Comparing with wave velocity and force, it is known that the time history curves of them show similar mountain shapes and the peak values happened almost at same time. Therefore, it is expected that positive correlation exists between wave force and velocity.

Based on former research, the following Eq. 1 is confirmed can evaluate tsunami wave force on bridge girder.

$$F_x = \frac{1}{2}\rho_w C_d v^2 A \qquad (1)$$

When computing wave force, the maximum wave velocity after smoothing measured by V3 was applied due to the velocity measured by V2 shows great volatility for repeat measurements of one case. A is the compression area by wave (here is assumed as girder lateral area).

By Eq. 1, the wave forces of all experimental cases were computed. As a consequence, the comparison of wave forces between calculation and measurement (the maximum wave forces after smoothing are used) is illustrated in Fig. 7. It is notable that the direct proportion relationship exists between wave forces by calculation and measurement. Furthermore, averagely the measurement is about 1.65 times as large as calculation.

The reason why measurement is larger than calculation can be explained as follows. Generally, when computing wave force, the maximum wave velocity right ahead of girder measured by V2 should be applied. However, due to great volatility of measurement of V2, the result of V3 is used for calculation temporarily. As shown in Fig. 8, as an image, if computing wave force by peak value of V2, the force of measurement (24N) is about 1.3 times larger than calculation (18N). Therefore, it is inferred that if the velocity at V2 can be measured accurately, the calculation will be close to measurement. And how to improve the precision of measurement at V2 is under consideration.

4. CONCLUSIONS

(1) From the analyses of video recording tsunami in Tohoku Area, the tsunami wave shape “steady flow with small height of bore wave” is found generally.

(2) From the experimental result, it is found that the time history curves of wave force and velocity show similar mountain shapes and the peak values happened almost at same time.

(3) By the comparison of wave forces between calculation (wave velocity from V3 is applied) and measurement, it is summarized that the wave forces from measurement shows direct proportion relationship with calculation and averagely the measurement result is 1.65 times as large as calculation.

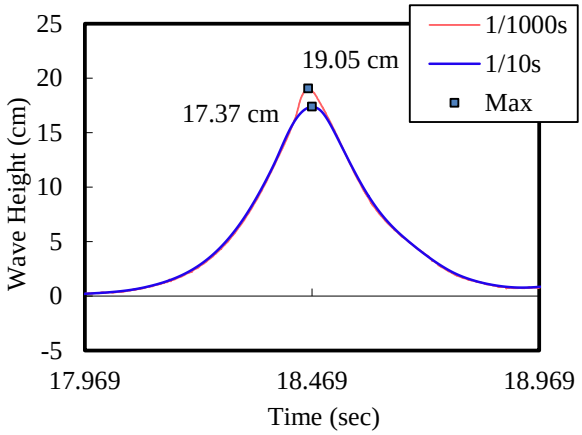

Fig. 5 Wave Height Variation

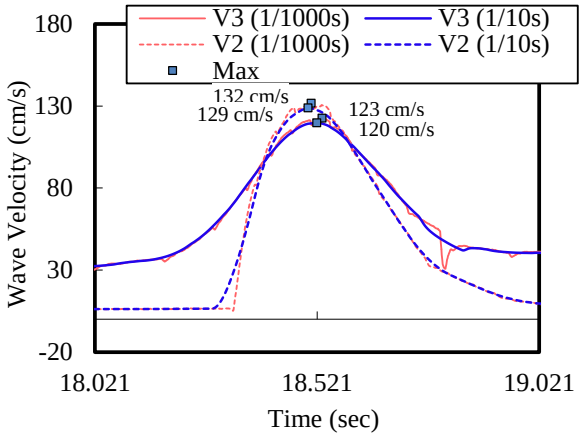

Fig. 6 Wave Velocity Variation (V2, V3)

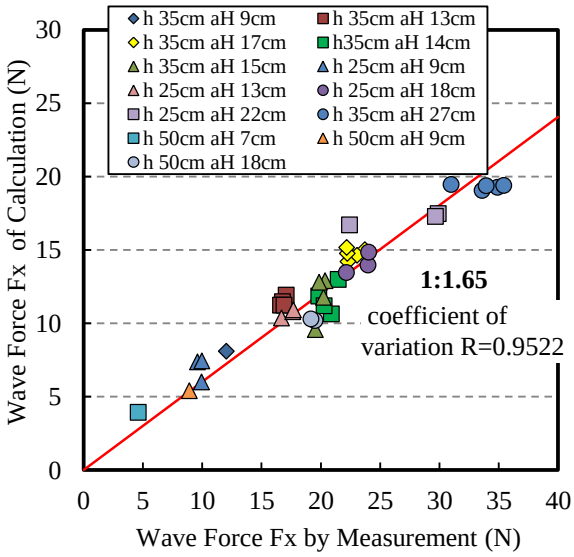

Fig. 7 Relationship between Wave Forces by Measurement and Calculation

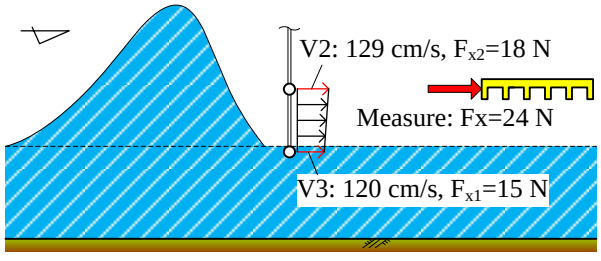

Fig. 8 Comparison of Wave Forces by V2 and V3