Study of Vertical Acting Force & Girder Position When Bridge Girder Affected by Solitary Wave

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1. Introduction

After the destructive tsunami damage on bridge girder caused by 2011 Tohoku Earthquake, many experimental studies have been done for grasping tsunami characteristic.

The authors have carried out a series of tsunami experiments (all cases have shown in Fig.1) about vertical acting force on bridge girder. They are experiments of bare wave, wave level, wave height, girder position & girder shape parameters. In this paper wave experiments by girder position parameter are used to the vertical acting force study.

2. Experimental Setup

The girder model (scale: 1/50) and the setup of 13 pressure gauges, which measure the pressure that affects to the girder model, are shown in Fig.2. The model relative position z/a_H is considered to be parameters. 3 solitary wave experiments, which are z/a_H =0.8, z/a_H =0.4 and z/a_H =0, have been carried out. In which, case z/a_H =0.4 is the standard case and the others are girder position parameter cases.

As plotted in Fig. 2, in the water channel, the wave making plate is applied to make a solitary flow. Wave gauge H6 is used obtain the flow depth at the girder model position. And the force transducer T1 is set at the center of the water channel to measure wave vertical force Fz.

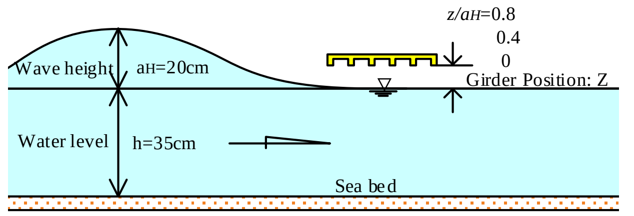
3. Experimental Results

In this section, the experimental results of standard case z/a_H =0.4 is introduced in detail; while for case z/a_H = 0, just the specific result is explained, for case z/a_H = 0.8 all results are omitted because of limitation by space.

For standard case, when vertical acting force to girder reaches peak, tsunami acting situation of wave surface and pressure distribution has shown in Fig.3. Compared with wave face without girder model, wave force is combined by water masses [a] and [b], which appeared at the front of girder model and behind girder model, respectively as shown in Fig. 3-(a). What's more, the wave force, which affects to the bottom of girder model, trends move girder to its upper-right.

As illustrated in Fig. 3-(b), assuming that the upward vertical force is positive, the upper integral force Fzpu and lower integral force Fzpl have been integrated to be -2.0N and 48N, respectively when vertical acting force reaches peak. So that the biggest vertical integral force Fzpmax= 48N-2N=46N. Moreover, the lower load distribution of girder is trapezoid.

Vertical wave acting force applying on the girder model of standard case has shown in Fig. 4 and the time history of measured vertical force Fz, full integral force Fzp, upper



Series	Bore wave	aH	Z	h	Girder shape	Sea bed	Cases
Series 1	Have	7, 8, 12	4.8	5	Standard	Have	3
		10	4.8, -4~8 (1cmpich)				14
		11,18,23,28	4.8	15			4
		25	4.8, -4~18 (1cmpich)				24
	No	11	4.8, -4~10 (1cmpich)				16
Series 2	Bore wave	aH	Z/aH	h	Girder shape	Sea bed	Cases
	No	20	0,0.8	35	Standard	No	2
		10,15,20,25	0.4		Standard, Overhang,1.5D,2.0D,1.4B,1.8B,2.1B		28
		5,7.5,10		15			21
	Have	10					7
		20		35			7

Fig. 1 Experiment cases

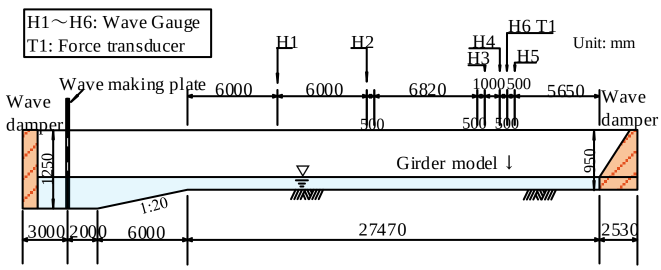
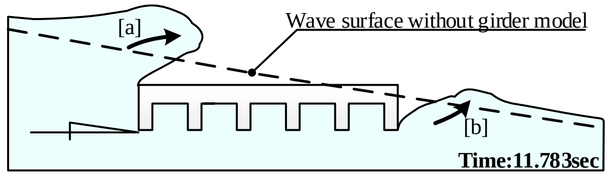
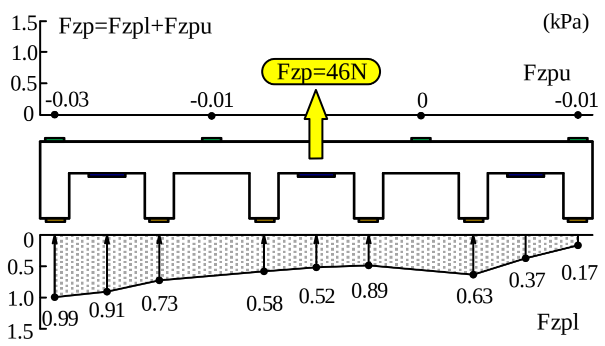


Fig. 2 Water channel panorama



(a) Wave surface



(b) Pressure distribution

Fig. 3 Tsunami acting situation when vertical acting force reach peak of case z/a_H =0.4 (11.783s) integral force Fzpu and lower integral force Fzpl have been plotted. Compared Fzp with Fz, the time history shape are same almost before Fzpu acts to girder model. Moreover, the peak values of Fz and Fzpu are 48N and 46N, respectively. There are small difference between the two peak values so that measured result has high reliability. Compared Fzpu with Fzpl, when Fz reached peak Fzpu do not act to the girder. So that it can be said that lower integral force is the predominant one for the biggest vertical force.

Vertical wave acting force applying on the girder model of case z/a_H =0 has shown in Fig. 5 and the peak values of Fz 53N is same with Fzp 58N almost, while the peak value of Fzpl is 80N which is bigger than Fz. Wave surface near girder when Fzp reaches peak has shown in Fig. 6. Compared with Fig.3, z/a_H = 0 case both girder lower pressure and girder upper pressure act to girder when Fzp reaches peak.

So that it is noted that vertical force is influenced by both of lower girder force and upper girder force when girder model position near to initial wave level. Because of the lower girder position, girder is overflowed earlier and the higher inundation height of z/a_H =0 case leads Fzplmax to bigger than that of other cases.

4. Relationship between girder position and vertical acting force

As illustrated by Fig. 7, Fzp is full integral force and Fzpl, Fzpu is integral force of the lower girder model and upper girder model, respectively. Peak values of full integral force and lower integral force are plotted. For z/a_H =0.8 & z/a_H =0.4 cases, Fzplmax and Fzpmax occur at the same time. While, for z/a_H =0 case Fzlmax ([b] time) occurs later than Fzmax([a] time) and Fzpmax trends to be smaller than Fzplmax. Wave height a_H is the measured peak value at H6 which is 6th wave gauge located in the side of girder model.

Based on the data of Fig. 7, it is noted that both lower integral force Fzpl and Fzp increases with girder position z/a_H decreasing. While Fzpmax trends to smaller than Fzplmax when girder position closes to the initial wave surface.

5. Conclusions

(1) From the solitary wave experiment of case z/a_H =0.4, it is noted that the measured vertical force Fz and all integral force Fzp increases with lower integral force Fzpl increasing. And lower integral force plays the leading role in vertical force acting to girder. When Fzp reach to peak 46N the pressure distribution at the bottom of girder model is trapezoid.

(2) According to the girder position parameter solitary wave experiments, the relationship between full integral vertical force Fzp and girder position z/a_H is summarized as below: Full integral force Fzp decreases as girder position z/a_H increases. Because of the higher inundation height, the full integral vertical force Fzp trends to be smaller than Fzpl when girder position close to the initial wave surface.

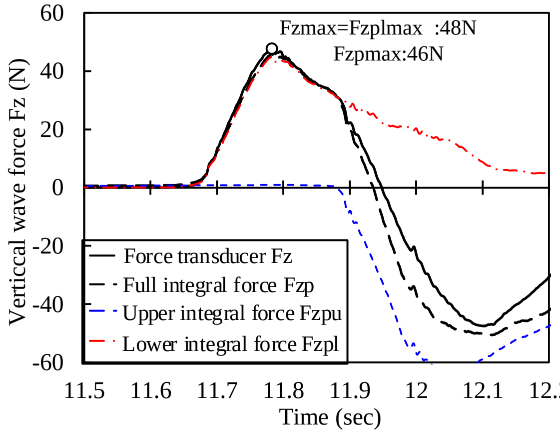


Fig. 4 Vertical acting force on girder model (z/a_H =0.4)

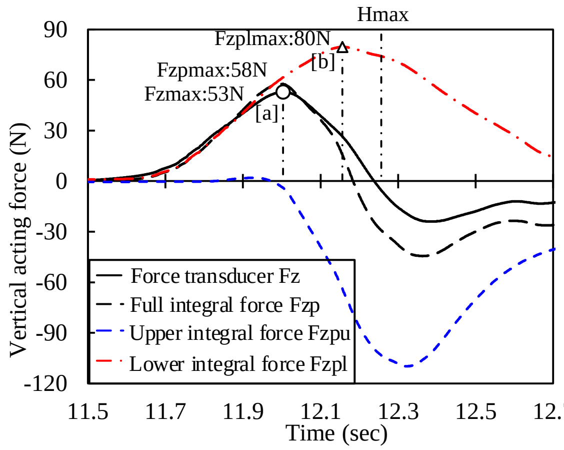


Fig. 5 Vertical acting force on girder model (z/a_H =0)

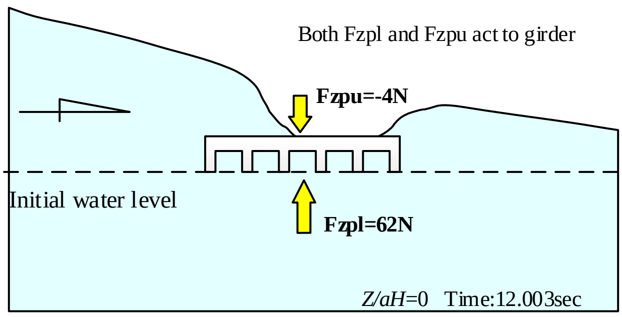


Fig. 6 Wave surface when Fz reaches peak (z/a_H =0)

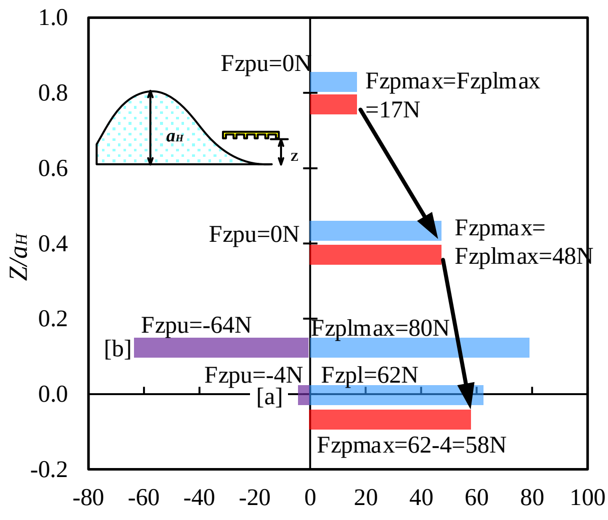


Fig. 7 Relationship between Z/a_H and vertical acting force