Investigation of Tsunami Hydrodynamic Loads Acting on a Series of Two Bridges Structure

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1. Introduction

In the coastal regions, tsunami waves have been considered as the primary causes of failures and severe damage of coastal structures. The catastrophic events of tsunami have forced the importance of protecting structures from the destructive power of tsunami. The bridge structure is a vital component in the road network system, especially during the evacuating or rehabilitating period due to tsunami disaster. Therefore, evaluating the structure stability of coastal bridge structures due to tsunami hydraulic loads is a need, in order to provide guidelines for the design of bridge infrastructures built in areas with potential risk of tsunami. The expansion of coastal area required the double or two bridges design to satisfy the road network capacity demand. However, there has not been investigation related tsunami hydraulic impact to this model. Therefore, this research performs experimental works to investigate the hydrodynamic impacts of tsunami bore type on the two bridges model.

2. Experimental Works

The physical simulations of hydraulic tsunami bores impacting bridge structure was carried out in a two dimensional open channel flume measuring 12.0 m in length, 0.4 m in width, and 0.4 m in height. The schematic of the testing facilities is described in **Fig. 1.**

A sluice gate was installed in the upstream of the flume. The impoundment depths (*h1*) cases, of 0.2m, 0.25m and 0.3m were carried out. The hydraulic bore was generated by a rapid opening mechanism of the sluice gate. A bridge structure with 1.2cm thickness was set on the height of 7.6 cm from the bottom of flume. Initial water level, *h2*, was set as 1.8cm. This study investigated two cases of bridge models, i.ein the case of one bridge and two bridges. The two bridges model was set by installing second bridge in the distance of 3.9 cm behind the first bridge. Two wave gauges for measuring the water surface elevation*W1* and *W2* were installed on the upstream of the bridge, whereas *W3* was on the downstream. To record the pressure profile of the hydrodynamic loads due to the tsunami bore, pressure gauges were placed on the front and rear side of the first bridge. The experimental investigation of pressure profiles on the top and bottom side of the bridge and numerical modeling are pending.

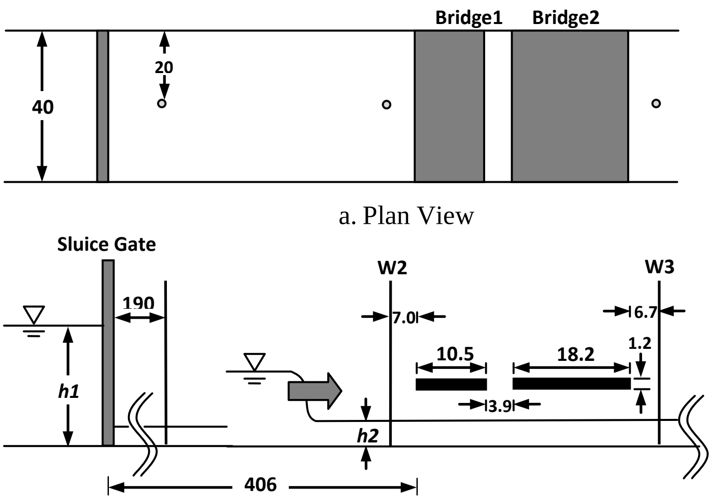


Fig.1 Experimental setup, unit :cm

3. Result and Discussion

Water surface profilesat*W2*, which was located 7.0cm in front of the first bridge and at W3, which was set on 28.8cm behind the second bridge structure in case of one bridge are presented in **Fig.2**. At both locations, the water surfaces quickly elevate when the bore pass the measurement points. After the sharp increase in each profile, the water levels decrease gradually to a certain value with fluctuation. This fluctuation occurred due to the existence of bridge structure. The water elevation becomes higher with increase of impoundment height.

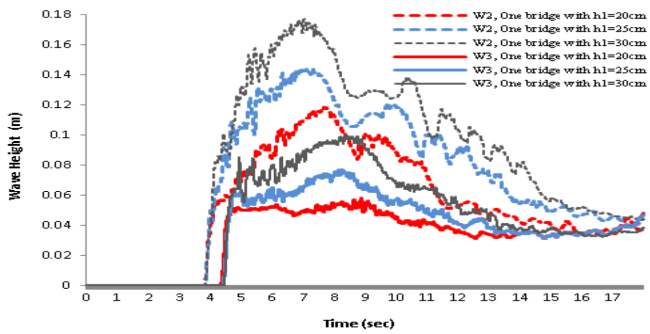


Fig.2 Water surface elevations at W2 and W3 in case of one bridge

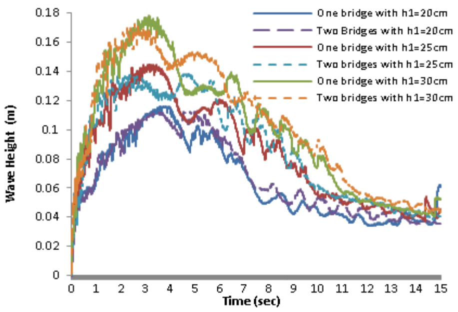
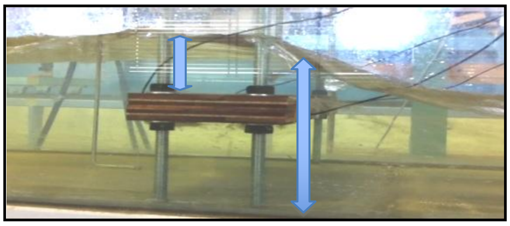
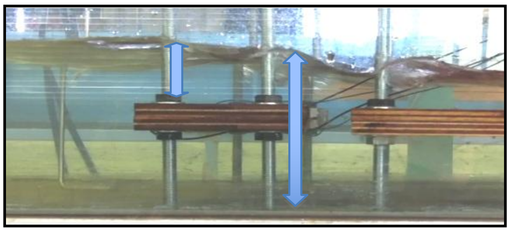


Fig.3 Water surface elevations at *W2*



a).



b).

Fig.4 Snapshot of inundated flow overtopping over the bridges. a). One bridge b). Two bridges

Water surface profiles at *W2* in case of one bridge and two bridges model are presented in **Fig.3**.As can be seen in this figure, the water surface profiles are similar to those in the case of one bridge. The existence of second bridge caused configuration of inundation flow become longer in the vicinity of the bridge. Though, there is no significant difference on the wave arrival time at *W3*.

Based on the observation as shown in **Fig.4**, there was significant increase the inundation depth just after the first bridge, while the inundation depth above the first bridge was slightly higher. It occurred because after the wave overtopped the first bridge, the wave continuously flowed above the second bridge. In addition, the increased water surface elevation generated more pressure on the structure.

Fig. 5 shows the wave pressure profile on the front and rear face of first bridge in case of 30 cm of impoundment height. Each of profiles clearly shows the high initial impact and long sustained impact pressures. The installation of second bridge has less effect on the magnitude of initial pressure, however significant differences are found on the sustained pressure on both locations

Fig.6 shows the maximum sustain wave pressure on the front and rear side of the bridge structures in all impoundment heights. In case of 20cm impoundment height, the water starts overtopping the structure in around two seconds after hitting front face of the first bridge. Based on the observation, only small amount water overtopped the bridge, which resulted to small pressures on both locations. The increase of impoundment height to 25cm and 30cm causes the amount of overtopped water becomes larger. This phenomenon leads to higher sustain wave pressure. In the case of two bridges, this figure indicates that the existence of the second bridge significantly enhances the magnitude of maximum sustain wave pressure on the rear side of first bridge. On the other hand, the increases of inundation depth in this location due to the existence of the second bridge causes the insignificant enhancements of maximum wave sustain pressure on the front side of the first bridge.

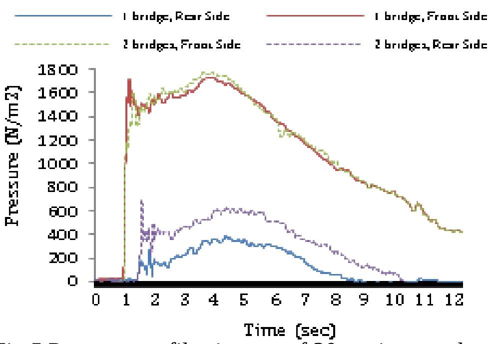


Fig.5 Pressure profiles in case of 30 cm impoundment height

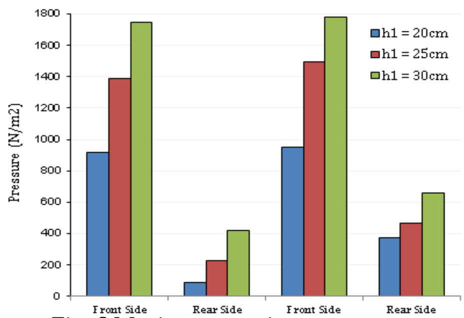


Fig. 6 Maximum sustain wave pressure **W1**

4. Conclusions

The experiments have been conducted to identify the characteristic of water surface profile and tsunami wave pressure acting on bridge structures. This study concludes that the existence of additional bridge installed behind the bridge structure tends to increase the water surface elevation over the bridge. The increase of inundated flow overtopping the bridge relates to the enhancement of sustain wave pressure on both front and rear side of the bridge. Furthermore, the significant increase of maximum sustain wave pressure occurred on the rear side of the bridge.

References

1) SHOJI, G. and MORIYAMA, T. , 2007, Evaluation of the Structural Fragility of a Bridge Structure Subjected to a Tsunami Wave Load, Journal of Natural Disaster Science, Volume 29, Number 2

2) Tirindelli, M., Cuomo, G., Allsop, W., Lamberti, A., 2003, Wave-in-Deck Forces on Jetties and Related Structures, Proceedings of the Thirteenth International off shore and Polar Engineering Conference Honolulu, Hawaii, USA

3) Lukkunaprasit, T., Lau, T.L., Ruangrassamee, A. and Ohmachi, T., 2008, Tsunami Wave Loading on A Bridge Deck with Perforations, The 14th World Conference on Earthquake Engineering, Beijing, China