Experiments on leveling of impact force, and effective ratio of slits in fairing for reducing damage of bridges by tsunami

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Summary

In the 2011 Japan Tohoku Earthquake off the Pacific coast, the superstructures of bridges were swept away by the tsunami. The authors conducted hydraulic experiments in order to understand the forces that tsunami exert on bridges, and to consider corresponding measures for bridges that will be effective against tsunami. With respect to one such measure, an experimental study was performed to determine whether the force of a tsunami can be reduced by attaching fairings to a bridge. From previous studies, it has been found that fairings are effective for horizontal drag, but it is not effective for vertical drag because of the buoyancy. Therefore, hydraulic experiments were conducted on the effect of having to open a slit in the fairing, to smooth the flow of water into the fairing within.

Keywords: tsunami; bridge; damage; 2011 Tohoku Earthquake off the Pacific coast; fairing; slit fairing; hydraulic experiment

1. Introduction

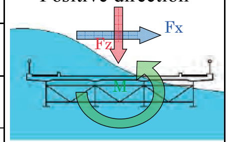
The 2011 Tohoku Earthquake off the Pacific coast inflicted serious damage on the Tohoku district of Japan, and many human lives and large amounts of property were lost. Although many bridges suffered damage from this earthquake, the most serious was that in which the superstructure was swept away by the tsunami. Tsunami resistant design has yet to be established. In this paper, the authors focused on fairings is effective in reducing the horizontal force, an experiment was conducted to provide a slit in the fairing in order to prevent an increase in the lift force, and to level the impact force.

2. Experiment of the slits fairings

It was possible to reduce the horizontal force using fairings. As shown in Table 1, especially box-shaped fairing is effective. However, tends to increase for a vertical force was observed. Therefore, for the purpose of reducing the horizontal force without increasing the vertical force, the experiments of slits fairing was conducted.

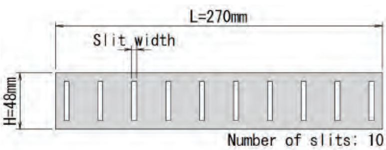
Fig. 1 shows the shape of the slits fairings. Settings of the slit were shown in Table 2. As for the slit shape, it was prepared for six kinds by each L-shaped fairing and Box-shaped fairing. Fig. 2 shows Drag coefficient and Lift coefficient with the slits fairing. Slit rate 100% in the Fig. 15 shows the state of without fairing. Drag coefficient is increased as the slit rate increases at the impact state. This is because the horizontal drag is increased by slitting. In a steady state, the drag coefficient shows a gradual similar trend. However, in the case of box-shaped slits fairings it can be seen that it is constant irrespective of the slit rate. Lift coefficient is decreased as the slit rate increases at the impact state of the Box-shaped slits fairings. This is because the upper lift is reduced by a slit. However, the slit rate over 50% is a constant. It can be seen that it is constant regardless of the slit rate for L-shaped slits fairings.

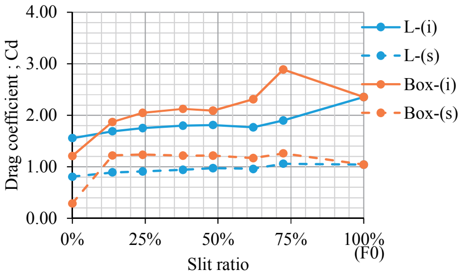
Table 1: Value of the component forces [No slit]

Name	Fairing type	Impact-State (maximum)					Steady-State (average)				
		Fx(i)	Fz(i)-	Fz(i)+	M(i)-	M(i)+	Fx(s)	Fz(s)	M(s)	Vx	Positive direction 
		N	N	N	Nm	Nm	N	N	Nm	cm/s	
F0	No fairing	15.27	-5.44	8.07	-2.09	0.62	6.76	5.84	-0.47	100	
F2	L-shaped	10.10	-4.25	12.13	-1.29	0.88	5.23	5.88	-0.11	100	
FB0	Box-shaped	7.84	-20.35	3.75	-1.22	0.74	4.57	1.88	0.00	100	

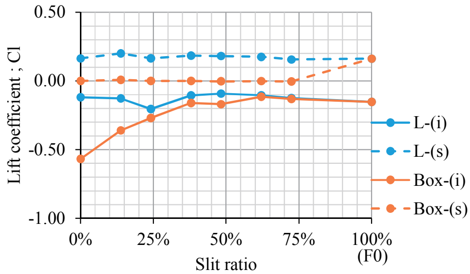
This value was converted to the flow velocity of 100 cm/s.

Table 2: Setting of the slits

Fairing shape		Slit width	Slit ratio		CG
L	Box	mm	%	 Slit ratio = Slit width / L	 SF14  SFB14
SF4	SFB4	4	13.79		
SF7	SFB7	7	24.14		
SF11	SFB11	11	37.93		
SF14	SFB14	14	48.28		
SF18	SFB18	18	62.07		
SF21	SFB21	21	72.41		



(a) Drag Coefficient



(b) lift Coefficient

Fig.2: Drag coefficient and Lift coefficient with the slits fairings

3. Conclusions

For the purpose of leveling of impact force and reduction of lift force, experiments of slit fairing effective to reduce horizontal drag were performed. Through an examination of the experimental results, the following conclusions were obtained;

1) By increasing the slit rate in the L-shaped fairing, horizontal drag increases gradually at the impact state and the steady state. In box-shaped fairing, as compared with the L-shaped fairing, the horizontal drag force is increased greatly by providing the slit.

2) By providing a slit in the box-shaped fairing, lift coefficient at the impact is greatly reduced. This indicates that the slits is effective in reducing lift force at the impact state. For other, there was no change in the lift coefficient.

3) For leveling of impact force due to the slits, a clear result was not obtained.

By experiments, it was found that it is possible to reduce the lift force at the impact state by providing a slit in the box-shaped fairing. However, drag coefficient was increased by the provision of the slits in the box-shaped fairing in comparison with the L-shaped fairing.