Model Experiments of a Novel Anti-collision Facility for Wanzhou Yangtze River Road Bridge

Xiqin Ma*, Changqi Yang*, Kui Yu**,Yang Liu**,Hechuan Zeng*

**Department of Mechanics Engineering, College of Resource & Environmental Science, Chongqing University, Chongqing, 400044, China*

***Southwestern Hydro Engineering Research Institute For Water Way, Chongqing Jiaotong University, Chongqing, 400016, China*

Summary A novel anti-collision facility was proposed for Wanzhou Yangtze River Road Bridge. The 1:100 global hydraulic models contained the novel anti-collision facility and river channel nearby the bridge was built to conduct the dynamic and static water collision experiments. 1:25 half hydraulic model of river channel was established to observe and verify the operation status of the new anti-collision facility. According to the result of 1:100 dynamic water model experiments, we found that 1,000-DWT longitudinal flow model ship and 5,000-DWT bulbous bow model ship didn't side tumbling and climb on the anti-collision facility. Furthermore, the result of the 1:25 model experiment displayed the normal operation status that anti-collision facility lifted with the change of water lever. Moreover, the 1:100 static water model experiments verified the reliability of numerical simulation of the new anti-collision facility showed that the displacement, collision force and reaction force between numerical simulation and model experiments have good consistency.

Introduction

The possibility of collision between vessel and arch bridge has been increased because of the water level raising of Three Gorges Dam. The various types of protective structures for bridge structures have been widely applied and may be considered by the engineer in practice, such as fender systems, pile-supported systems, dolphin protection, island protection, and floating protection systems, etc. [1-4]. However, anti-collision facilities above were not suitable for arch bridge except for floating protection systems, because they will impact the flow pattern and are difficult to construct and high cost. Nevertheless, floating protection facility must take reasonable fixed method. In this study, a novel self-floating arch shape anti-collision facility was designed, which can be floated on the water and fixed on the mountain as shown in Fig.1.Its anti-collision ability and security was evaluated to avoid the damage of arch bridge. The method of scale model experiment was taken to analyze the dynamic properties of self-floating arch shape anti-collision facility. Meanwhile, the scale model experiments established according to similarity theory were conducted to verify the reliability of finite element algorithm and the operation status of the facility.

Model experiments

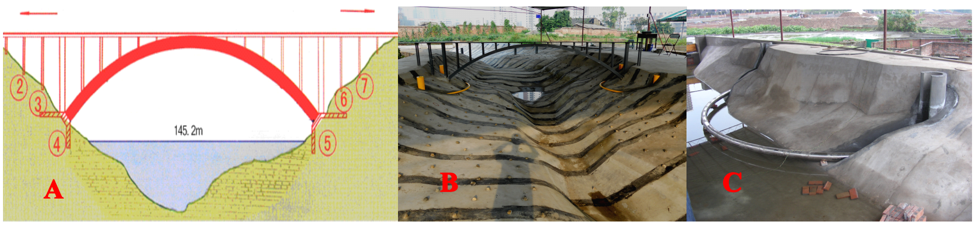

Fig.1.A The terrain schematic diagram of Wanzhou Yangtze River Road Bridge.

B The 1:100 model of river channel and anti-collision facility. C The 1:25 model of river channel and anti-collision facility.

The 1:100 and 1:25 model of river channel nearby bridge and the new anti-collision facility were established. Considering the size of field, the ability of water supply and the size of ship model, the length of the 1:100 and the 1:25 model are 50m and 12.5m respectively from upstream to downstream of bridge's axes. The water power similarity condition was shown as follows, listed in Table.1. As is shown in Fig.1.A is the terrain schematic diagram of wanzhou Yangtze River Road Bridge, and the Fig.1.B displayed the 1:100 model of river channel and anti-collision facility, and Fig.1.C exhibited the 1:25 model of half river channel and the anti-collision facility.

Table.1 The water power similarity conditions

name	variable	formula	scale
Geometric scale	λ_L, λ_h	$\lambda_L=\lambda_h$	100
Velocity scale	λ_v, λ_ω, λ_{vc}	$\lambda_v=\lambda_\omega=\lambda_{vc}=\lambda_h^{1/2}$	10
Flow scale	λ_Q	$\lambda_Q=\lambda_L\lambda_h\lambda_v$	100000
Roughness scale	λ_n	$\lambda_n=\lambda_n^{1/6}(\lambda_n/\lambda_n)^{1/2}$	2.15
Time scale	λ_t	$\lambda_t=\lambda_L/\lambda_v$	10

The scale model 1:100 and 1:25 was established according to similarity theory to verify the status of the ships (1,000-DWT longitudinal flow model ship and 5,000-DWT bulbous bow model ship) in terms of side tumbling and climbing on the facility and anti-collision facility's self-operation status respectively. Due to the limitation of processing technology, we simplified the cross-section of the anti-collision arch as a ring. Then, the size of the ring in scale model 1:100 and 1:25 were determined by global stiffness similarity theory. The material of the model 1:100 was PVC (E=2.0GPa) and 1:25 was steel (E=200GPa). The global stiffness similarity was completed by formula (1-1) as follows, and global stiffness similarity model was shown in Fig.2.

$$y=\sum\int\frac{\overline{F}_N F_{NP}}{EA}ds+\sum\int\frac{\overline{M}M_P}{EI}ds \tag{1-1}$$

Where $\overline{F}_N,\overline{F}_Q,\overline{M}$ were internal force coursed by unit load, and F_{NP},F_{QP},M_P were internal force coursed by actual load.

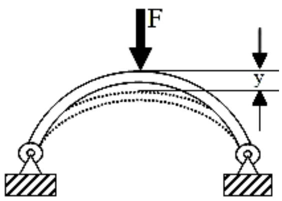

Fig.2 The global stiffness similarity model

Fig.3.A. 1:100 model experiment in the dynamic water .B. 1:25 model self-operation status experiment C. static water collision experiment

y=0.228m was calculated under the static loaded 5,000kN on the actual structure. Therefore, y should be 0.00228m under the static load 5N in the 1:100 scale model. We can obtain the thickness t of the ring in the model of 1:100 was 0.0005m and 1:25 was 0.002m. Then, 1:100 model collision experiment in the dynamic water and static water and 1:25 model anti-collision device self-operation status experiment were conducted, as shown in Fig.3. The 1:100 model experiment done in the static water was intended to verify the reliability of finite element explicit dynamic algorithm, and in the dynamic water was aimed to observe the side tumbling and climbing of the ship. Moreover, 1:25 model experiment was done to determine whether the device will be locked or not when it operated in the guide well.

Results

According to the result of 1:100 dynamic water model experiments, we found that 1,000-DWT longitudinal flow model ship and 5,000-DWT bulbous bow model ship didn't side tumbling and climb on the anti-collision facility. Furthermore, the result of the 1:25 model experiment displayed the normal operation status that anti-collision facility lifted with the change of water lever. Moreover, the 1:100 model static water collision experiment show that the error of displacement, collision force and reaction force between numerical simulation and model experiments is 7.4%, 10.4% and 8.63% respectively.

Reference

[1] AASHTO. Guide Specification and Commentary for Vessel Collision Design of Highway Bridges. Washington, D.C., 1991

[2] AASHTO. Guide Specification and Commentary for Vessel Collision Design of Highway Bridges (the second edtion). Washington, D.C., 2009

[3] Wei Fan, Wancheng Yuan. Numerical Analysis of Floating Protection System for Bridge Structure Subjected to Vessel Impact(CA).ICETCE.2011

[4] Pan Jin, Weiguo Wu. The design and analysis of pile protection devices for the Qiantang River Bridge(CA).ASME.2010.