A Novel Anti-collision Facility of Wanzhou Yangtze River Highway Bridge

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Summary In this study, a novel self-floating arch anti-collision facility for wanzhou yangtze river highway bridge was proposed. Its ability of anti-collision and security was evaluated by numerical simulation and model experiments. Here, a bulbous bow ship loaded 5000 Ton impacted the anti-collision facility with the speed of 3.5m/s in the normal direction of arch of 1/8 of arch. As a result, 59.2% of kinetic energy was transformed into elastic deformation energy. In its interaction area, 10.1% and 2.6% of kinetic energy was dissipated by plastic deformation of facility and ship respectively, and the remaining was transformed into kinetic energy of ship and facility after flicked the ship. Furthermore, the scale model 1:100 was established to verify the reliability of finite element calculation. The error of displacement, collision force and reaction force between numerical simulation and model experiments is 7.4%, 10.4% and 8.63% respectively. In the 1:25 model experiment, the facility operated normally with the change of water level.

Introduction

The possibility of collision between vessel and arch bridge has been increased when 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. Finite element method 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.

Finite element analysis of anti-collision facility

To describe the characteristics of vessel during an impact event, the fine finite element model of 5,000- DWT ship as shown in Fig.2 was developed using ABAQUS and UG. In this model, 4-node shell element of the ship-bow was adopted. At the head of the ship, the size of element was approximately 0.25m and at the other part of the ship, the size of the element was about 1m. In the finite element model, floating condition was considered in order to simulate the side tumbling and climbing of the vessel. Algorithm of buoyancy is based on VDLOAD distribution load subroutine in the ABAQUS, loaded the distribution load $f = \rho_{water} g h_{depthunderwater}$ on the integration point of vessel and protection device. In this study, the harsh condition was analyzed. A ship loaded 5000-DWT impacted the anti-collision facility in the normal direction of 1/8 of arch with the speed of 3.5m/s, which was displayed in Fig.3. As a result, 59.2% of kinetic energy was transformed into elastic deformation energy. In its interaction area, 10.1% and 2.6% of kinetic energy was dissipated by plastic deformation of facility and ship respectively, and the remaining was transformed into kinetic energy of ship and facility after flicked the ship.

Fig.1 The effect drawing of anti-collision device

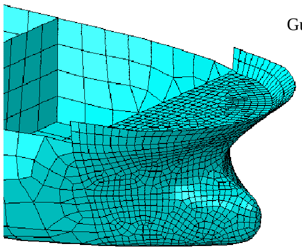

Fig.2 Model of a ship

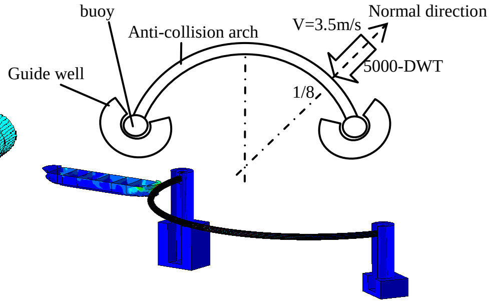

Fig.3 Collision condition and the whole model

Scale model experiments

The scale model 1:100 and 1:25 was established according to similarity theory to verify the reliability of finite element analysis and anti-collision facility's self-operation. 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.4.

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

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.

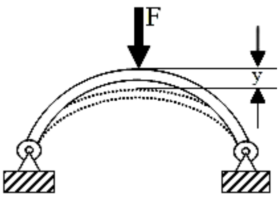

Fig.4 The global stiffness similarity model

Fig.5.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.5. 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 results of finite element analysis, the anti-collision facility can absorb 69.3% kinematic energy by elastic deformation and part plastic deformation. The error of displacement, collision force and reaction force between finite element calculation and model experiments is 7.4%, 10.4% and 8.63% respectively in the static water collision experiment. As was observed in the 1:100 dynamic water model experiment and 1:25 self-operation status experiment, the ship didn't side tumbling and climbing on the device, and device operated normally with the change of water level.

Reference

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