Ship Collision Protection Device for Zhanjiang Bay Bridge

Yinghong CAO
Vice Chief Engineer
Guangdong Road&Bridge Construction Development Co, Guangzhou, China
caoyinghong@163.com

Yinghong Cao, born 1971, received his Ph.D degree in bridge engineering from the Tongji Univ. in 1999. project manager and chief engineer of Zhanjiang Bay Bridge from 2001~2007

Linge LUO
Vice Chief Engineer
Zhanjiang Bay Bridge Co. Ltd. Zhanjiang, China
luolg@hwb.com.cn

Linge Cao, born 1967, received his civil engineering degree from the Chongqing Jiaotong Univ. in 1989, vice chief engineer of Zhanjiang Bay Bridge Co. Ltd from 2003~2008

Ying ZHOU
Associate Professor
South China Univ. of Tech.
Guangzhou, China
zhouy@scut.edu.cn

Ying Zhou, born 1970, received her Ph.D in bridge engineering from Southwest Jiaotong Univ. in 1997. post doctoral researcher in Wuhan Univ. from 1997~1999

Summary

This paper reported the design and implementation of an energy-absorption type ship collision protection device for Zhanjiang Bay Bridge in China. The main bridge is a cable stayed bridge with center span of 480m, crossing a 50,000 tonnage navigation route. The maximum possible impact force by ship to main pier is about 84MN. A flexible energy-absorption SCPD was developed and applied to this bridge. This double-case self-floated SCPD consists of inner steel case, external steel case and viscous-elastic rings between them. It can reduce the maximum impact force to below 50MN, while the maximum capacity of main pier is 60MN. The capacity of this SCPD was verified by dynamic impact simulation analysis. A new 3 level protection design strategy which generated during the development of SCPD was introduced in this paper.

Keywords: Bridge; Ship; Collision; Protection; Flexible; Energy absorption; Device

1. Introduction

Due to limited span length of bridge and continue growing tonnage of ships, it is sometimes unavoidable that collision may occur between ship and bridge, causing bridge collapse, ship sinking, casualties and property losses. How to protect bridge against ship collision is a long-term issue. Zhanjiang Bay Bridge, a cable stayed bridge with main span of 480m, encountered such problem because the span is just enough for a 50,000 tonnage ship causing high collision risk, while the capability of main pier 60MN is less than the maximum impact force 84MN by such ship. There are several types of ship collision protection device (SCPD). Artificial island can provide best protection to bridge but cost most and occupy too much navigating space. Fender piles and cable moored float are effective for small boats. Ship fender can only be used to buffer ships during berthing in very low speed. Steel cofferdam can be used to protect bridge against ship collision in navigating speed but it is easily damaged and need repair in case of each collision. These common protection structures are all not suitable to this bridge for insufficient free space, deep water, soft pile ground base and extremely high impact force. A new type of SCPD called Flexible Energy Absorption SCPD was proposed during the concept design of this bridge. The Department of Communication of Guangdong Province authorized a key research project in 2002 to investigate the feasibility of such SCPD. This project was conducted by Zhanjiang Bay Bridge Co. Ltd, cooperated with several research institutes.

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2. Design of Flexible Energy Absorption SCPD

This device was designed as self-float type double cofferdams around periphery of piers in ring-shaped arrangement. It consists of internal steel casing, elastic energy absorption rings, external steel casing and connecting components. Internal and external steel casings provide buoyancy to make the structure float by itself, moving up and down along with sea-level change.

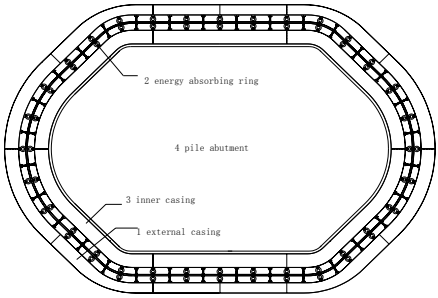

Fig. 1: General layout of SCPD

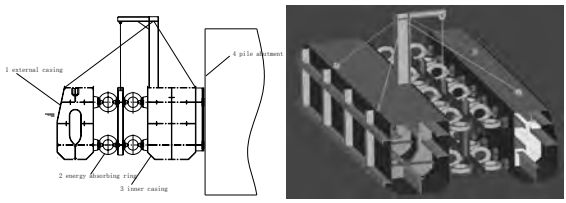

Fig. 2: Cross section and 3D model SCPD

External steel casing will recede while ship collision, causing several elastic energy absorption rings to deform and causing internal steel casing to press piers so that reacting force can be jointly offered to make the ship head slide. On one hand, the whole structure can buffer impact by absorbing impact energy and reducing impact force through recession and deformation. On the other hand, the bridge pier, ship head and the device itself can all be protected from damage due to such buffer in most cases. (Fig. 1 and 2)

3. Dynamic Analysis for SCPD

To validate the collision protection capacity of flexible energy absorption and collision protection device, researchers established computer finite element dynamic simulation analysis models of ship, bridge and collision protection device based on the principle of impact dynamics to carry out full-course collision simulation analysis.

Table 1: Maximum impact force at different angles

1	Angle of impact (°)	13°	45°	52°
2	Occurrence Time of max. value (s)	5.22	1.68	5.33
3	Instantaneous max. value (MN)	4.97	35.4	56.1
4	Equivalent time (s)	6.0	4.4	6.0
5	Equivalent impact force (MN)	2.03	11.7	35.2

The analysis results (table 1) show that, when a 50,000-tonnage ship impacts collision protection device at an angle of 0°～45°, collision protection device can sufficiently absorb deformation energy, and turn the ship head. Impact force on bearing abutment of the pier is smaller than 60MN. The device is almost undamaged and can be restored by itself. Collision protection effect of the whole device is satisfying.

4. Manufacture and Installation

Fig. 3: Completed SCPD

Through invitation for bid, collision protection device was manufactured and installed by state-owned Wuchang Shipyard. This device was manufactured at Heavy Industry Base of Wuchang Shipyard. It was finally assembled near Zhanjiang Bay Bridge and floating installed at sea. The installation completed in June, 2007. (fig. 3) Two third of the 3 meter high cofferdams is under water.