International Journal of Offshore and Polar Engineering
Vol. 10, No. 3, September 2000 (ISSN 1053-5381)

Dynamic Characteristics of a New Material Protective Device for Ship Collision

Kuniaki Shoji, Tokiko Takabayashi, Shigeo Mita
Tokyo University of Mercantile Marine, Tokyo, Japan

Chisato Nonomura
Toyobo Co. Ltd. Research Center, Otsu, Japan

ABSTRACT

As regards collisions of ships with bridges, serious accidents do not happen these days but the number of accidents has not decreased yet. The record indicates an average of at least 10 collision accidents per year. In these circumstances various kinds of bridge pier protection systems have been planned. The protection system should be designed to protect not only the bridge structure but also the vessel against serious damage. The Pelprene protective device reported here is one of the new material protective devices for attachment to the bridge pier to absorb colliding energy by elastic deformation of the protection. This paper reports on the effectiveness of this protection system by dynamic model experiment. To study the characteristics, finite-element analysis was also performed and compared with the experimental result. The results show good agreement.

INTRODUCTION

In recent years, many bridges and offshore structures have been constructed near ship waterways. For example, the Seto Bridge, which is one of the Honshu-Shikoku Connecting Bridges, was opened in 1988; the Tokyo Bay Crossing Bridge-Tunnel was opened in December 1997; and the Akashi Kaikyo Bridge of Honshu-Shikoku Connecting Bridges was opened in April 1998. In Denmark, the Great Belt Bridge-Tunnel was also constructed. Owing to the increase of bridge and offshore structures as well as marine traffic, ship collision accidents with these structures have been increasing. The accidents at the Tasman Bridge in Australia in 1975, the Tjorn Bridge in Sweden in 1980 and the Sunshine Skyway Bridge in the U.S. in 1980 were brought about by ship collision. After 1980 serious accidents have not happened, but the number of accidents has not decreased yet. The record indicates an average of at least 10 collision accidents per year.

To keep these structures safe from ship collision accidents, various kinds of protective devices have been planned (Iwai et al., 1983; Shoji et al., 1985, 1994). Most protective devices are like the fender system of wharfs and should be designed to protect not only the bridge structure but also the vessel against serious damage. The Pelprene protective device shown here is one of these protective devices absorbing colliding energy by elastic deformation of the protective device. Pelprene is a new material, a kind of thermoplastic elastomer with intermediate characteristics between rubber and plastic.

In this paper the effectiveness of this protective device was studied by a dynamic model experiment. In this experiment, the dynamic indentation of the ship model to the Pelprene protective device was performed. The result of this experiment was found to agree well with the result of the static indentation test.

Received March 3, 1999; revised manuscript received by editors June 27, 2000. The original version (prior to the final revised manuscript) was presented at the Ninth International Offshore and Polar Engineering Conference (ISOPE-99), Brest, France, May 24-29, 1999.

KEY WORDS: Ship collision, bridge pier, protective device, thermoplastic elastomer, bow indentation, colliding energy, collision absorbing efficiency.

SHIP-BOW MODEL INDENTATION TEST

In order to verify the characteristics of the Pelprene protective device, the ship-bow model indentation test was executed at the Institute of Marine Science and Technology of the Tokyo University of Mercantile Marine. In this experiment, a moving ship-bow model was made to collide with the Pelprene protective device model. The bow model was wedge-shaped and made of well-stiffened 16-mm steel plate. The entrance angle of the bow model was 35°. The tip of the bow was a round bar of radius r = 50 mm or r = 10 mm. The experimental apparatus is shown in Fig. 1 and a product piece of Pelprene protective device in Fig. 2. Experimental conditions are shown in Table 1. The type of collision, form and characteristics of the protective device, colliding weight (W) and colliding speed (Vi) were changed. 4AR indicates a product piece 200 mm x 200 mm x 50 mm as shown in Fig. 2 with a girth band, 5 x 5 mounds and 2.0-mm plate thickness. 2CR is a product piece of 200 mm x 200 mm x 40 mm with a girth band, 7 x 7 mounds and 2.4-mm plate thickness. 2AQ is the same product piece as 2CR but without the girth band. The number used to identify the material indicates flexural strength. The larger this number becomes, the greater the flexural modulus of the material. Table 2 indicates the physical and chemical properties of these materials.

The experimental conditions of front collision, oblique collision and raked stem collision indicate a variation of the colliding angle or stem rake. Repeated collision means that the test is repeated several times in the same condition. Continuous collision also means that the test is repeated several times, but the colliding speed is increased gradually and the colliding weight is also increased.

Fig. 3 shows the data of the entrance angle of ships constructed recently. In this figure, the entrance angle near the load waterline is found distributed between 20° and 100°. For this experiment the entrance angle of 35° was adopted. This value was also referred from several experiments (Nagasawa et al., 1977; Shoji et al., 1994b, 1995).

Observed data were colliding speed (V_i), rebounding speed (V_o), colliding acceleration (a), bow indentation (δ), reaction force