Probabilistic Load Model for Ship-Bridge Collision Using Monte Carlo Simulation

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Summary

In designing a bridge crossing navigable waterway, ship-bridge collision is the one of the critical extreme events. Due to its inherent uncertainties, probabilistic design approaches have been mainly adopted, in which the probability of failure or collapse of the whole bridge system should be estimated. Therefore, it is crucial that appropriate probabilistic models should be employed for collision loads and resistances of the piers. In this paper, a method is presented for developing probabilistic load models for ship-bridge collision. The difficulties arise from the fact that the resultant collision force, which is a function of other random variables such as speed of a ship, collision angle and position, etc. Furthermore, statistical data of actual ship-bridge collision events are very rare. Thus, a simulation based approach is proposed for the probabilistic load model for ship-bridge collision. The collision force model is derived from the combination of the probability of the collision event and the conditional probability distribution of the impact load of each collision case. In this approach, models are also incorporated for initial ship position, aberrance probability and human intervention stopping ship before collision. For the impact load, uncertainties such as collision angles, velocities and the weight of colliding ship are also considered. The final probabilistiy distribution of collision load is constructed based on Monte Carlo simulation method. A numerical example of an actual cable-stayed bridge is presented for the demonstration of the proposed model.

Keywords: ship-bridge collision; impact load; probabilistic load model; simulation based approach.

1. Introduction

A bridge located in navigable waterway is exposed to the risk of ship collision. As an extreme event, ship collision has very rare frequency but when it is occurred, the consequence may be critical to bridge structures and even the collapse of the bridge can be leaded. Hence, the comprehensive analysis of ship collision risk should be required in designing the bridge. In general a risk is defined as the product of the frequency and the consequence of the hazard considered. In case of ship-bridge collision, the frequency corresponds to the occurring probability of a collision event and the consequence to the magnitude of collision. At this point, the probability of collision event is determined by navigational characteristics of operating ships, and the magnitude of collision is depending on collision situation, i.e. type of colliding ship, incident angle, and impact speed. Table 1 shows the general process of probability based design against ship-bridge collision recommended by AASHTO guide specifications[1] and EUROCODE[2]. In this process, the uncertainties due to environmental factors or human errors are considered to define the aberrance probability and the collision probability by using the statistical data and a probabilistic model. However, the impact force is usually estimated by empirical formula in which the uncertainties in various collision situations are not explicitly considered. For example, AASHTO guide specifications suggest a

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