Precast Concrete Segmental Bridge Piers under Ship Impact

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Summary

Because of the convenience in construction and quality control, the precast segmental method has been increasingly used not only in bridge decks, but also in bridge piers. For example, this is being used in the bridge piers of the approaches in the Hong Kong-Zhuhai-Macao Bridge currently under construction. As ship collision with bridge piers is one of the most frequent accidents that may lead to bridge failure, attention has been drawn to the safety of precast concrete segmental bridge piers under ship impact.

A numerical study was carried out to analyse the structural behaviour of typical bridge piers under ship impact. Two different designs of bridge pier were considered, namely the cast-in-place reinforced concrete and post-tensioned precast concrete segmental versions. Finite element analyses of the bridge piers under ship impact were conducted taking into account the joints, prestressing tendons, material nonlinearity, etc. The effects of location of ship impact were examined. Results of impact force and the displacement at pier top end were examined. In the light of the numerical results, the design impact loads prescribed by the Chinese bridge design code, Eurocode and AASHTO LRFD Bridge Design Specifications were evaluated.

Keywords: Bridge piers; numerical simulation; post-tensioning; precast segments; ship impact

1. Introduction

Modern match-casting technology has made precast segmental construction a standard method of bridge building. The method is increasingly applied to construct bridge decks and piers because of its convenient construction, reliable quality control, reduced disruption and environmental impact, simpler on-site temporary works, better site safety, etc. [1]. These advantages are particularly valuable to the building of bridges over water. A notable example is the approach viaduct for the Hong Kong-Zhuhai-Macao Bridge currently under construction.

However, bridge structures over water are vulnerable to vessel collision for various reasons, which may cause damage or even collapse of bridges. Ship collision with bridge piers is one of the most common accidents in waterborne traffic [2, 3]. Typically a segmental pier is built on cast in situ pile cap and kicker segment with the precast segments assembled by post-tensioned tendons passing through ducts already cast in the segments. Compared with cast in situ concrete piers that are continuously reinforced, precast segmental concrete piers have inherent sections of weakness, including the epoxy joint between precast segments, and the base joint between the lowest precast segment and the in situ segment. Although each precast segment is properly reinforced, the strength of joints often relies primarily on the tendons. Once the joints open under the action of vessel collision, a pier may exhibit large inelastic deformation with little energy dissipation [4].

So far, the work on precast concrete segmental bridge piers has mainly focused on the development of structural system and seismic performance. Megally et al. [5] investigated the seismic performance of segment-to-segment joints in precast segmental concrete bridges. Zhan and Yu [6]

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