Dynamic Response of Bridge Tower by Wave Forces

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ABSTRACT

In this paper, dynamic response of sea-crossing bridge tower under wave forces is studied. With a numerical example, three-dimensional finite element model of bridge tower is established. Then, the random wave forces acting on bridge tower are simulated using Morison equation and spectrum of ocean wave. Furthermore, the dynamic response of the bridge tower is evaluated. Finally, the dynamic analysis results are compared with those of static analysis by equivalent static method. The results show that the dynamic results are very larger than the static results. It is unsafe for calculating wave forces acting on sea-crossing bridge using equivalent static method.

KEY WORDS: Random wave forces; dynamic response; interaction of wave and structure; bridge tower.

INTRODUCTION

With the rapid development of bridge technology, the constructions of sea-crossing bridges have been placed on the agenda, such as Hong Kong-Zhuhai-Macao Sea-Crossing Project, Qiongzhou Strait Project, Gibraltar Strait Project and so on. The constructions of sea-crossing bridges are facing very tough challenges, and one of them is huge tidal wave. With the growth of sea-crossing bridge’s span, the bridge tower has been developed to be much higher and softer which increases its sensitivity to wave loads. In harsh marine environment conditions, wave exhibits random characteristics, while the interaction effects between wave and bridge tower are more significant, then, wave forces acting on bridge tower are huge, therefore, the dynamic response of bridge tower may exceeds the permissible limits, leading to deflections, accelerations, large forces, and even failure. However, few studies have been done on the dynamic response of sea-crossing bridge tower under random wave forces. In related bridge design code, wave forces on vertical column are based on deterministic wave theory, without considering the dynamic interaction of wave and structure. During bridge design and practice, the maximum of wave forces are often regarded as static forces directly acting on structures. Thus, this paper will discuss the subject that whether the wave forces acting on sea-crossing bridge tower are acceptable or not without considering wave’s random characteristics and interaction of wave and structure.

Studies on dynamic problem of offshore platform under wave forces are useful for references here, in which a part of them (Bi, 1986; Lin, 1986; Zhong, 1987; Kawano, 1999) used frequency domain analysis method, and other part of them (Hahn, 1995; Yang, 1997; Mendes, 2003; Jia, 2008) used time domain analysis method. It should be noticed that frequency domain analysis method cannot properly deal with the nonlinear load effects induced from Morison's equation, the variation of the water surface causing the intermittency of the wave loading and variation of buoyancy forces on members in the splash zone. In those literatures, the random wave forces acting on structures are simulated using Morison equation and spectrum of ocean wave. However, there are much differences between offshore platform and bridge tower, like structure form, marine environment condition, and so on. The research conclusions for offshore platform can not be used to guide the design of sea-crossing bridge directly. Since 1980s, some literatures about wave forces on bridge foundation and its dynamic response were reported. Yu (1988) studied the wave actions on a cylinder in 3-D random waves by experiment. Zhang (2005) calculated the time history of wave forces on a pier foundation of a bridge and its dynamic response in frequency domain. Lan (2006) studied the vertical hydrodynamic forces on a circular slab near free surface by water waves. Liu (2006) pointed out that the environment impacts, local scouring around the piers and hydrodynamic forces on the piled structures are three major hydrodynamic problems associated with the design and construction of sea-crossing bridges. Numerical simulations and physical model investigations were applied to research the mechanism of the complicated turbulent flows and hydrodynamic forces due to the irregular wave-current combination. Liu (2007) reported the experiment results of wave current forces on piles group of the East Sea Bridge in China. Although several investigations have been carried out for the wave forces acting on bridge pile or foundation, little attention has been focused on dynamic response of bridges subjected to wave forces. McIver (1986) studied the enhancement of wave forces due to interaction effects for the case of two adjacent, parallel, floating bridges using the method of matched eigenfunction expansions. Mohammad (1998) proposed a method to analyse discrete pontoon floating bridge taking into account complete hydrodynamic interaction between the pontoons on the basis of a three-dimensional source distribution method.

At present, physical model investigation is still the main tool for the