System reliability evaluation of long-span cable-stayed bridges

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Summary

The long span cable-stayed bridges exhibit important geometric nonlinearity that should be considered in their analysis and design. Unless simplifying assumptions are made, system reliability evaluation of these structures is complex and can be very time consuming. This paper proposed an approximate method to conduct system reliability analysis of long span cable-stayed bridges. The method integrates the advantages of the response surface method (RSM), finite element method (FEM), β-unzipping method and the improved product of conditional marginal (I-PCM) method. The accuracy and efficiency of the method is demonstrated through one numerical example. Then the method is used to evaluate the system reliability of cable-stayed bridges. The example cable-stayed bridge is the Sutong Bridge with a main span length of 1088 m built in China. The obtained results clearly show the applicability and merits of the proposed method.

Keywords: cable-stayed bridges; geometric nonlinearity; finite element method; response surface method; system reliability.

1. Introduction

Cable-stayed bridges have made rapid developments over the past 40 years. Central span length of cable-stayed bridges has exceeded 1000m. The static behavior of cable-stayed bridges has been studied by many researchers, including Hegab [1], Nazmy and Abdel-Ghaffar [2], Self and Dilger [3]. These studies were based on the assumption of complete determinacy of structural parameters. This is usually referred to as deterministic analysis. In reality, however, there are uncertainties in design variables. These uncertainties include geometric properties (cross-sectional properties and dimensions), material mechanical properties (modulus and strength, etc), load magnitude and distribution, etc. Thus the deterministic analysis cannot provide complete information regarding static behaviour of cable-stayed bridges. Therefore, the static behaviour of cable-stayed bridges should be studied under a probabilistic viewpoint.

Reliability analysis provides the tool of incorporating structural modeling uncertainties in the analysis of the structural response by describing the uncertainties as random variables. The reliability of a cable-stayed bridge may be estimated at two levels: component level and system level. At the level of components (i.e., individual performance criteria), limit state formulations and efficient analytical and simulation procedures have been developed for reliability estimation [4]. However, because the calculation of the failure probability for a system is generally difficult even if the potential failure modes are known or can be identified, the evaluation of system reliability for bridge structures has rarely been reported. Imai and Frangopol [5] investigated the system reliability of suspension bridges under different loading and damage scenarios, and identified the most influential random variables on the system reliability of suspension bridges by using a sensitivity analysis. Except a simple study done by Bruneau [6], there is no readily available information on evaluation of the system reliability of cable-stayed bridges. Therefore, the purpose of the current study is to estimate the system reliability of cable-stayed bridges. For this purpose, an approximate

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