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Fatigue analysis of long-span suspension bridges under multiple loading: Case study

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ABSTRACT

Long-span suspension bridges are often subject to multiple types of dynamic loads, especially those located in wind-prone regions and carrying both trains and road vehicles. Fatigue assessment shall be performed to ensure the safety and functionality of the bridges. This paper proposes a framework for fatigue analysis of a long-span suspension bridge under multiple loading by integrating computer simulation with structural health monitoring system. By taking the Tsing Ma Bridge in Hong Kong as an example, a computationally efficient engineering approach is first proposed for dynamic stress analysis of the bridge under railway, highway and wind loading. The fatigue-critical locations are then determined for key bridge components, and databases of the dynamic stress responses at the critical locations are established. The time histories of dynamic stresses induced by individual loading during the design life of the bridge are generated based on the databases. The corresponding stress time histories due to the combined action of multiple loading are also compiled. Finally, fatigue analysis is performed to compute the cumulative fatigue damage over the design life of 120 years. The results indicate that it is necessary to consider the combined effect of multiple loading in the fatigue analysis of long-span suspension bridges.

1. Introduction

Many long-span suspension bridges have been built around the world, and most of these bridges are steel structures. Research carried out by the American Society of Civil Engineers (ASCE) indicates that 80%–90% of failures in steel structures are related to fatigue and fracture [1]. Fatigue analysis is thus essential and imperative in the design of steel bridges [2,3]. There is an approach, which is based on measured strain responses, applied for the fatigue assessment of several steel bridges in the past two decades [4–7]. Although this method is considered to be an accurate way to evaluate the fatigue life of steel bridges, it has some limitations for long-span suspension bridges. For instance, the evaluation is limited to critical locations installed with strain gauges but the identification of critical locations may not be an easy task for long-span suspension bridges under multiple loading. It is also not economical to install strain gauges at all critical locations of a long-span suspension bridge, and not every fatigue-critical location is suitable for sensor installation. To overcome these problems, a finite element method (FEM) integrated with field measurements has been proposed to investigate fatigue damage induced by a particular loading, such as railway loading [8–10], highway loading [11–13], and wind loading [14,15]. Nevertheless, given the long-span period involved in fatigue damage accumulation in long-span suspension bridges and the complexity of the dynamic stress responses due to the combined action of multiple loading, a little research has been carried out for fatigue analysis of long-span suspension bridges under multiple loading.

This paper proposes a general framework for fatigue analysis of a long-span suspension bridge under multiple loading by integrating computer simulation with measurement data from a Wind and Structural Health Monitoring System (WASHMS). By taking the Tsing Ma suspension bridge in Hong Kong as an example, a computationally efficient engineering approach is first proposed for dynamic stress analysis of the bridge under railway, highway and wind loading. The fatigue-critical locations are then determined for key bridge components, and databases of the dynamic stress responses at the critical locations are established. 120 years of time histories of the dynamic stresses induced

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