Dynamic Analysis of a Suspension Bridge with a Floating Girder

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Abstract

A continuum model for a three-span suspension bridge with a floating girder is presented to investigate its dynamic behavior under moving loads and vertical support motions. This model can consider hangers' extensibility. Coupled differential equations for the vertical displacements of a main cable and a girder subjected to external loads are presented. Equations of motion in matrix form are obtained by introducing the Galerkin method with shape functions for the main cable and the floating girder. A numerical example is used to verify the continuum model against a finite element model.

Keywords: suspension bridge; continuum model; floating girder; dynamic analysis; moving loads; vertical support motions.

1 Introduction

For suspension bridges, finite element method (FEM) models usually require high computational resources because of their many thousands of degrees of freedom and need a time-consuming modelling procedure including an initial equilibrium state analysis. In contrast, continuum models based on the deflection theory require much fewer degrees of freedom because of their simple governing equations and do not need an initial equilibrium state analysis. Therefore, these continuum models can be useful in a preliminary design to determine bridge properties and to independently verify complex FEM models.

A floating girder in three-span suspension bridges is continuous and not vertically supported at its intersections with towers. Therefore, this girder has vertical differential motions from a main cable at towers. This girder makes it possible to avoid installation of its expansion joints and cross-beams under it at the intersections, and is usually adopted to ensure a train's runnability or to obtain an efficient design for seismic and wind resistance.

In most of continuum models for suspension bridges, hangers which vertically connect a main cable and a girder together are assumed to be inextensible. Thus, these models cannot present any vertical differential motion between a main cable and a girder. This fact implies that these models cannot be applied to a suspension bridge with a floating girder. Therefore, a continuum model for this bridge is presented in this paper.

2 Continuum model

Figure 1 shows a suspended floating girder, where m_c and m_g are the uniform masses of the main cable and girder per unit horizontal length, respectively; g is the gravitational acceleration; E_c, E_h, and E_g are the elastic moduli of the main cable, hangers, and girder, respectively; A_c and A_h are the cross-sectional areas of the main cable and hangers, respectively; I_g is the moment of inertia of the girder; L is the span length; f is the cable sag

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