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Nonlinear Dynamic Analysis of Cable-Stayed Bridges Excited by Moving Vehicles

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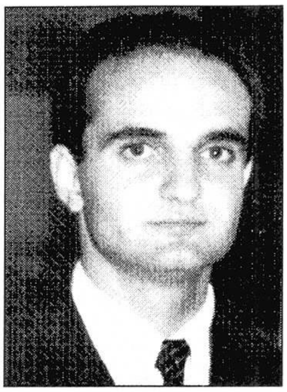

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Abstract

The dynamic response of bridges subjected to moving vehicles is complicated. This is because the dynamic effects induced by moving vehicles on the bridge are greatly influenced by the interaction between the vehicles and the bridge structure. Although several long span cable-stayed bridges are being build or proposed for future bridges, little is known about their dynamic behavior under the action of moving vehicles. As cable-stayed bridges are getting longer, lighter, and more slender, accurate procedures need to be developed that can lead to a thorough understanding and a realistic prediction of the structural response due to traffic loading. It is well known that large deflections and vibrations caused by dynamic tire forces of heavy vehicles can lead to bridge deterioration and eventually increasing maintenance costs and decreasing service life of the bridge structure.

In this paper, a method for modeling and analysis of the nonlinear dynamic response of cable-stayed bridges excited by moving vehicles is presented. The bridge structure is discretized utilizing the nonlinear finite element method and the dynamic response is evaluated using a combined Newton-Newmark algorithm. A beam element, which includes geometrically nonlinear effects and is derived using a consistent mass formulation, is adopted for modeling the girder and the pylons. Whereas, a two-node catenary cable element derived using exact analytical expressions for the elastic catenary, is adopted for modeling the cables. All sources of geometric nonlinearity and other important factors that significantly influence the dynamic response, such as bridge damping and bridge-vehicle interaction, are considered.

The vehicle model used in this study is a so-called suspension model that includes both primary and secondary vehicle suspension systems. As the vehicle equation of motion is coupled to the bridge equation of motion through the interaction force existing at the contact point of the two systems, an iterative procedure is adopted to solve these two sets of equations.

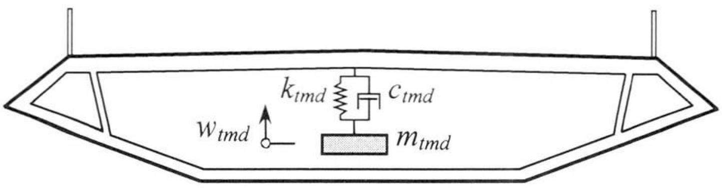

Figure 1: Cross section of bridge girder with a tuned mass damper, TMD

As energy dissipation in cable-stayed bridges is very low and may often not be enough on its own to suppress vibrations, the efficiency of a so-called tuned mass damper on controlling traffic-induced vibrations, is investigated. A tuned mass damper is a vibration absorber tuned to a particular mode of the bridge and consists of a mass, a viscous damper and a linear spring, see Figure 1.

A simple cable-stayed bridge model is analyzed to highlight the dynamic effects and to show the influence of vehicle speed, bridge damping, and a tuned mass damper on the bridge dynamic response.