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Article

Model Bridge Span Traversed by a Heavy Mass: Analysis and Experimental Verification

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Abstract: In this work, we investigate the transient response of a model bridge traversed by a heavy mass moving with constant velocity. Two response regimes are identified, namely forced vibrations followed by free vibrations as the moving mass goes past the far support of the simply supported span of the bridge. Despite this being a classical problem in structural dynamics, there is an implicit assumption in the literature that moving loads possess masses that are at least an order of magnitude smaller than the mass of the bridge span that they traverse. This alludes to interaction problems involving secondary systems, whose presence does not alter the basic characteristics of the primary system. In our case, the dynamic properties of the bridge span during the passage of a heavy mass change continuously over time, leading to an eigenvalue problem that is time dependent. During the free vibration regime, however, the bridge recovers the expected dynamic properties corresponding to its original configuration. Therefore, the aim here is the development of a mathematical model whose numerical solution is validated by comparison with experimental results recovered from an experiment involving a scaled bridge span traversed by a rolling mass. Following that, the target is to identify regions in the transient response of the bridge span that can be used for recovering the bridge's dynamic properties and subsequently trace the development of structural damage. In closing, the present work has ramifications in the development of structural health monitoring systems applicable to critical civil engineering infrastructure, such as railway and highway bridges.

Keywords: bridge model; moving loads; modal analysis; experimental verification; transient response; frequency spectra

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1. Introduction

The subject of moving loads on beams dates back to the 19th century, following the development of railways that necessitated the construction of metallic bridges across rivers, valleys and other types of irregular topography. At the same time, there was a parallel effort in developing mathematical models for this engineering type of problem, see, for instance, the early treatise by Renaudot [1] on representing a mass rolling over a beam. Starting from the 1960s onwards with the seminal work by Fryba [2], much work, both analytic and numerical, has been carried out on variations of the basic problem of a single load moving with constant speed over a single span. These include the cases of multiple spans, multiple moving loads, loads that accelerate or decelerate etc. Furthermore, the point load itself has evolved to become a structural sub-system by itself in possession of a mass, a stiffness and a damper in order to better model the passing vehicle's suspension system, see, for instance, Liu et al. [3]. Further studies along these lines were performed by Green and Cebon [4], who examined a simply supported highway bridge traversed by a single degree-of-freedom vehicle model and derived six non-dimensional parameters that quantified the degree of interaction between vehicle and bridge. The same authors expanded their original study to include the dynamic bridge response to a given set of wheel loads and also performed field measurements on a highway bridge to validate their