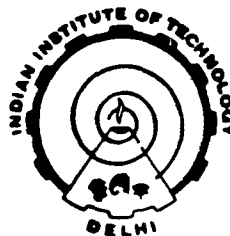


DYNAMIC ANALYSIS OF HIGHWAY BRIDGES UNDER MOVING VEHICLES

By

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*Thesis submitted
in fulfilment of the requirements for
the award of the degree of*
DOCTOR OF PHILOSOPHY



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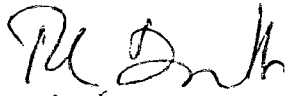
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CERTIFICATE

This is to certify that the thesis entitled, "**Dynamic Behaviour of Highway Bridges under Moving Vehicles**", being submitted by **Mr. P. K. Chatterjee**, to the Indian Institute of Technology, Delhi, for the award of the degree of '**Doctor of Philosophy**' in Civil Engineering is a record of the bonafide research work carried out by him under our supervision and guidance. He has fulfilled the requirements for submission of this thesis, which to the best of our knowledge, has reached the requisite standard.

The material contained in this thesis has not been submitted in part or full to any other University or Institute for the award of any degree or diploma.



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ABSTRACT

A continuum approach is presented for the dynamic analysis of different types of bridges for the vehicular movement. The types of bridges include truss bridge, cantilever bridge, arch bridge, multispan slab-and-girder bridge, cable-stayed bridge and suspension bridge. The formulation is first presented for a single moving load for which the dynamic response at any given point of time is obtained in terms of few recursive closed form expressions in each mode of vibration. The results of this analysis is then utilized for obtaining the response for single or multi-axle moving load idealized as a single, two-dimensional and three-dimensional sprung mass system. Mode shapes and frequencies of the continuum are extracted from eigen value problem which is determined from the dynamic stiffness of the system under various kinds of support and boundary condition consistent with the type of the bridge. In order to make the solution procedure applicable to different types of bridges, each type of bridge is suitably idealized.

The analysis considers the vehicle-pavement interactive force idealized as both linear and nonlinear (of hysteretic type), the effects of torsional coupling and random irregularity of the deck surface. The random bridge profiles are synthetically generated from specified power spectral density function of the pavement profile. The response of the bridge is obtained in time domain utilizing an iterative procedure to account for the nonlinear interactive force. For the dynamic response of cable-

stayed and suspension bridges warping effect of the deck, the effects of tower flexibility and different boundary conditions of the stiffening girder are duly considered in the analysis. For the cable-stayed bridge, the effect of axial force on bending and torsional deformation of the bridge deck (produced due to cable tension) is included in the dynamic formulation of the problem.

The results of the continuum method is verified with the reported results, and for certain cases, with the widely used lumped mass analysis. With the help of the proposed solution, parametric studies are conducted for different types of bridges mentioned above under vehicular movements. Some of the important results of the study are given in the following.

Continuum solution predicts the dynamic response of truss and arch bridges fairly well. The sprung mass model of vehicle provides less dynamic amplification factor (DAF) than that given by constant force idealization of the vehicle. If the nonlinearity of the interaction force for the sprung mass model is considered in the analysis, the DAF is further reduced. Also, 3-D model of vehicle predicts less value of DAF compared to 2-D and 1-D models for higher frequency ratio. Irregularity of the bridge pavement significantly enhances the DAF. For smooth bridge pavement, sprung and unsprung mass models of the vehicle generally provide same responses. For torsionally stiff bridges, like continuous beam-and-slab bridge, the eccentricity of vehicle path does not significantly influence the DAF, while for cable-stayed and suspension bridges it is not so. For lower speed of the vehicle, the eccentricity of the vehicle path may reduce

the DAF compared to the symmetrically placed vehicle for suspension bridge. The effect of torsional coupling is found to be important for bridges which are torsionally less stiff. The DAF is significantly influenced by the speed parameter and the frequency ratio for all types of bridges. The effects of tower flexibility (for cable-stayed bridge) and boundary conditions of stiffening girder (for suspension bridge) on the bridge frequencies are considerable.

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