PASSIVE AND HYBRID CONTROL OF STRUCTURES UNDER SEISMIC EXCITATION THROUGH VISCOELASTIC DAMPERS

By

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CERTIFICATE

This is to certify that the thesis entitled, "Passive and Hybrid Control of Structures Under Seismic Excitation Through Viscoelastic Dampers", being submitted by Mr. Ashutosh Kumar Shukla, 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 my supervision and guidance. He has fulfilled the requirements for submission of this thesis, which to the best of my 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

Structural control has become the subject of extensive research for the last decade. During this period, different types of control schemes like passive control, active control, and hybrid control have been proposed and many of these control schemes have also been implemented in practice. They include base isolation for seismic protection of buildings, Tuned Mass Dampers (TMDs) for reduction of wind induced vibration of tall buildings, Active TMD (ATMD) for both seismic and wind excitations of structures etc. Hybrid control schemes are generally favoured when a stringent control requirement is envisaged on some specific response quantities such as structural acceleration and inter-storey drift. Various active and passive control devices are combined together to evolve effective hybrid control schemes. Most widely reported Hybrid control schemes are those using ATMD and base isolation. Not much work is reported on hybrid control scheme using viscoelastic dampers (VEDs). As such reported literature on the passive control of building structures using VEDs for earthquake forces is not widely reported, although VEDs are easy to implement as compared to base isolation. The main reason is attributed to the economic considerations and lack of development of very effective VEDs. Keeping these in view, the present study deals with passive and hybrid control strategies using VEDs under seismic excitation.

In passive control, three different VED models viz. Kelvin model, Linear Hysteresis model, and Maxwell model are presented. For each model, three different analytical techniques in frequency domain are presented viz, an iterative pseudo force method, an approximate modal strain energy method, and an exact method using complex frequency response function of the system. The responses are obtained by the three different methods are compared for different combinations of VEDs giving rise to both

classically and non-classically damped cases. The results of the study indicate that pseudo-force method provides responses close to those obtained by the exact method. Performance of the modal strain energy method is good for classically damped system. Kelvin and Linear Hysteresis model provide nearly the same responses.

For obtaining the effective distribution of VEDs along the height of the building, four different types of distribution of VEDs along the height of the building is considered viz. uniform distribution, stepped distribution with heavy lower portion, stepped distribution with heavy upper portion and stepped distribution in the middle portion. Responses are obtained in frequency domain using spectral analysis for both narrow band and broad band stationary random ground motion for different type of distributions. Results of the study indicate that the stepped'distribution of the strength of VEDs provides better reduction in response compared to the uniform distribution; the nature of stepped distribution giving the best result depends upon the height of the building.

Important design issues related to structural applications of VEDs like the number, size and optimum locations of dampers for given structural parameters are then investigated. Optimum locations of passive VEDs are obtained using a controllability index, which is obtained with the help of the r.m.s. value of the inter-storey drift. The r.m.s. value of the responses obtained by spectral analysis for both narrow and broad band random ground motion. The optimal location is determined by searching the storey in which maximum inter storey drift occurs at any stage of the analysis. Responses obtained by using this, optimal placement of dampers are compared with those with other distribution of dampers described previously. The results of the study indicate that the optimal placement of passive VEDs provide better reduction in responses.

So far as the hybrid control strategy is concerned, it is developed by combining the Maxwell model of VED with the active tendon placed at the bottom storey of the frame. A

sliding mode control strategy is employed to obtain the control law for which a continuous controller is designed to drive the state trajectory into the sliding surface by considering the Lyapunov function. The control force is determined by suitable choices of weighting matrices, which provide relative weightages on the VED forces and penalties imposed on displacement and velocity. The responses for the control of building frame are obtained for synthetically generated ground excitations. An extensive parametric study on a twelve storey building frame is conducted to evaluate the effectiveness of hybrid control strategy. Results of the study indicate that the hybrid control scheme with active tendon and VEDs provide a significant reduction of acceleration response compared to passive control with VEDs only.

Hybrid control scheme using ATMD at the top of the building frame or an actuator placed at any floor level and VEDs placed at different storeys is also investigated. The control law is developed using the same concept of sliding mode control. The controlled responses are obtained for four different types of distribution of VEDs as mentioned before for synthetically generated earthquake records. An extensive parametric study is conducted to evaluate the relative performance of passive control, active control and hybrid control schemes. Results of the study show that the hybrid control scheme with ATMD provides higher control of absolute acceleration at higher storey levels compared to the active control scheme. As the actuators are placed towards the upper storey, better control of response with less control force is achieved for both hybrid and active control schemes.

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