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Seismic Response Control of Multi-Span Bridge Using Magnetorheological Dampers

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Abstract : The present study investigates the performance of a semi-active controller using magneto-rheological dampers (MR) for seismic response reduction of a multi-span bridge. The application of structural control to the structures during earthquake excitation involves numerous challenges such as proper formulation and selection of the control strategy, mathematical modeling of the system, uncertainty in system parameters and noisy measurements. These problems, however, need to be tackled in order to design and develop controllers which will efficiently perform in such complex systems. A control algorithm, which can accommodate un-certainty and imprecision compared to all the other algorithms mentioned so far, due to its inherent robustness and ability to cope with the parameter uncertainties and imprecisions, is the sliding mode algorithm. A sliding mode control algorithm is adopted in the present study due to its inherent stability and distinguished robustness to system parameter variation and external disturbances. In general a semi-active control scheme using an MR damper requires two nested controllers: (i) an overall system controller, which derives the control force required to be applied to the structure and (ii) an MR damper voltage controller which determines the voltage required to be supplied to the damper in order to generate the desired control force. In the present study a sliding mode algorithm is used to determine the desired optimal force. The function of the voltage controller is to command the damper to produce the desired force. The clipped optimal algorithm is used to find the command voltage supplied to the MR damper which is regulated by a semi active control law based on sliding mode algorithm. The main objective of the study is to propose a robust semi active control which can effectively control the responses of the bridge under real earthquake ground motions. Lumped mass model of the bridge is developed and time history analysis is carried out by solving the governing equations of motion in the state space form. The effectiveness of MR dampers is studied by analytical simulations by subjecting the bridge to real earthquake records. In this regard, it may also be noted that the performance of controllers depends, to a great extent, on the characteristics of the input ground motions. Therefore, in order to study the robustness of the controller in the present study, the performance of the controllers have been investigated for fourteen different earthquake ground motion records. The earthquakes are chosen in such a way that all possible characteristic variations can be accommodated. Out of these fourteen earthquakes, seven are near-field and seven are far-field. Also, these earthquakes are divided into different frequency contents, viz, low-frequency, medium-frequency, and high-frequency earthquakes. The responses of the controlled bridge are compared with the responses of the corresponding uncontrolled bridge (i.e., the bridge without any control devices). The results of the numerical study show that the sliding mode based semi-active control strategy can substantially reduce the seismic responses of the bridge showing a stable and robust performance for all the earthquakes.

Keywords : bridge, semi active control, sliding mode control, MR damper
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