Performance of a Base-Isolated Building with System Parameter Uncertainty Subjected to a Stochastic Earthquake

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(Received 21 May 2011, revised 17 February 2012, accepted 14 September 2012)

Base isolation has long been established as an effective tool for improving the seismic performance of structures. The effect of parameter uncertainty on the performance of base isolated structure is investigated in the present study. With the aid of the matrix perturbation theory and first-order Taylor series expansion, the total probability concept is used to evaluate the unconditional response of the system under parameter uncertainty. To do so, the conditional second-order information of responses are obtained by time domain nonlinear random vibration analysis through stochastic linearization. The implications of parametric uncertainty are illustrated in terms of the responses of interest in design applications. The lead rubber bearing isolator, isolating a multistoried building frame, is considered for numerical elucidation. It is observed that, although the randomness in a seismic event dominates, the uncertainty in the system parameters also affects the stochastic responses of the system. Particularly, the variance of the stochastic responses due to parameter uncertainty is notable.

1. INTRODUCTION

Vibration control technologies are widely acclaimed amongst researchers and practicing engineers as a viable alternative to traditional seismic design, which relies on energy dissipation through inelastic deformations of structural elements under earthquake-induced vibrations. In contrast to the traditional design, passive/active vibration control strategies substantially reduce the structural responses to ensure minimal damage to structures. A reduction of response is achieved through control systems, using base isolation (BI), tuned mass dampers, liquid column vibration absorbers, etc. Among these, BI systems have been used and globally accepted as an effective technology to reduce the seismic effects on strategically important structures as well as in retrofitting. In a BI system, the building rests on a system of isolators uncoupling the building from the horizontal component of the ground motion to effectively reduce the seismic load transmission to the structure. Various BI devices, such as rubber bearings (RB), lead rubber bearings (LRB), high-damping rubber bearings (HDRB), friction pendulums (FP), and resilient friction bearing isolators (R-FBI), are conventionally adopted for seismic protection of buildings, bridges, and other infrastructural facilities. These devices use different materials and design strategies to disconnect the superstructure motion from the ground. The effectiveness of BI systems and their performances has been extensively studied.[1–4] Several studies on stochastic response of base-isolated structures under random earthquakes are also notable.[5–7] These studies provide important insight into the behaviour of structures with BI systems. It is well established that the response of BI systems largely depends on the characteristics of the isolator, such as the yield strength for the LRB and RB types of isolator, optimal damping for R-FBI, and so on. Earlier studies have also provided parameters to ensure optimal performances.[7–9] In fact, studies on the optimum design of such systems are well known.[8–10] However, most of these works are based on deterministic descriptions of the parameters, characterizing the mechanical model of the superstructure-BI system as well as the stochastic load model for the earthquake. A major limitation of the deterministic approach is that the uncertainties in the performance-related decision variables cannot be included in the parameters for the process of optimization. Yet, the efficiency of such a system may be drastically reduced if the parameters are off tuned to the vibrating mode for which it is designed to suppress because of the unavoidable presence of uncertainty in the system parameters. Therefore, the passive vibration control of structures using BI system with uncertain parameters has attracted the interest of the vibration control community.

The developments in the field of passive vibration control by using various passive devices and considering system parameter uncertainty have been improved by many researchers.[11–18] However, this is not the case for BI systems. Studies on the performance of BI systems in connection with passive vibration control strategy are very limited. Benfratello et al. indicated that the effect of uncertainty on the response of structure with regard to base isolators and the ground motion filter parameters cannot be ignored.[19] Kawano et al. studied the effect