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Change in response of bridges isolated with LRBs due to lead core heating

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ABSTRACT

This study focuses on the response of seismic isolated bridges subjected to near-field ground motions with distinct pulse type behavior in terms of maximum isolator displacements (MIDs) and maximum isolator forces (MIFs) transferred to the substructure. The employed isolation systems are composed of lead rubber bearings (LRBs) with bi-linear force-deformation relations that consider cycle-to-cycle deterioration in the yield strength of the LRBs due to heating of the lead core. MIDs and MIFs with due consideration of cycle-to-cycle deterioration are compared with that of non-deteriorating ones. Bounding analyses are also performed for comparison purposes. Nonlinear response history analyses are conducted with two bins of ground motions recorded at different soil conditions to investigate the effect of ground motion characteristics. Results indicate that MIDs are overestimated by lower bound analyses when seismic isolated bridges are subjected to near-field motions with high velocity pulses especially for the bearings with higher Q/W ratios.

1. Introduction

Nonlinear response-history analyses of seismically isolated structures have generally been performed by employing bounding analysis to determine the response of isolated systems. Performing bounding analysis accounts for aging, contamination, history of loading, and heating effects. However, most of the difference between the upper and lower bound properties emerges due to heating effects [1,2]. Hence, analyses of seismic isolated bridges (SIBs) are performed both for the upper and lower bound characteristics of the isolators. The upper bound values usually result in the largest force demand on the substructure elements whereas the lower bound values result in the largest displacement demand on the isolators. For a lead rubber bearing (LRB), upper bound value is defined as the effective yield stress of the lead that is based on the first cycle of the bi-linear hysteretic behavior. On the other hand, lower bound value is based on the average value of the effective yield stress of lead in the first three cycles.

In two recently published companion papers where effect of heating on response of LRBs is studied, a theory to predict the reduction in the yield stress of the lead core and energy dissipation history of LRBs subjected to cyclic motion was presented [3] and verified [4]. Theory is based on estimation of temperature increase in the lead core and consequently, the yield stress of the lead is updated at each time step by using the instantaneous temperature. Those two studies are important because the characteristic values used in bounding analyses are appropriate for applications when there is a high seismicity with at least three cycles of large amplitude motion. On the other hand, when the motion has smaller number of cycles as in the case of near-field motions with high velocity pulses, bounding analysis may result in conservative estimation of maximum isolator displacements (MIDs) and maximum isolator forces (MIFs). This phenomenon can be supported by the fact that nearly 50% of the recorded near-field records contain two velocity pulses [5]. The model proposed by Kalpakidis and Constantinou [3] representing the cyclic deterioration in strength of LRBs is also implemented in OpenSees [6] structural analysis program and verified by comparing the results with the experimental data [7]. Although several researches have been conducted to assess the performance of SIBs subjected to near-field motions, none of them considered a deteriorating bi-linear hysteretic behavior due to temperature increase in the lead core under cyclic motion for LRBs. Hence, there is a need to investigate the effect of temperature-dependent behavior of LRBs on the response of SIBs. Results of such a research may result in a more sound and economical design of SIBs subjected to near-field motions.

2. Research objectives and methodology

The main objective of the study presented herein is to perform a thorough parametric research to evaluate effect of temperature-dependent hysteretic behavior of LRBs on the performance of SIBs.

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