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Investigation of the Seismic Responses of Base-isolated Buildings Under the Influence of Near-field Rround Motions

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ABSTRACT: Due to destructive effects of near-field earthquakes on building structures, this paper attempts to investigate the seismic behavior of base-isolated building frames under the effect of near-field ground motions using the non-linear time history analyses (NLTHAs). For this purpose, two steel moment-resisting medium-rise frames including 9 and 12-story ones were isolated using the lead-rubber base isolation system considering three levels of stiffness i.e. Hard (H), Normal (N) and Soft (S) isolators. Non-linear time history analyses (NLTHAs) were conducted using different sets of near-field ground motions with forward directivity, fling step and no pulse characteristics. Also, for the purpose of comparison, the NLRHA was carried out using a set of far-field ground motion records. The effect of isolator stiffness under different types of ground motions as well as the effect of pulse period on the seismic responses is scrutinized. The results showed that the change in the stiffness of isolation system from hard type to soft and moderate types (that increases the damping and period of the structure) reduces the seismic demands of the structure. Also, the story drifts of base-isolated building frames with soft isolator (more damping) are smaller than those with hard and moderate types for different values of pulse period, T_p. On the other hand, the sensitivity of the responses of base-isolated building frames with hard isolators (low damping) to pulse period is large.

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1- Introduction

Applying base isolation to engineering structures started in 1960s [1]. In a base-isolated building, the structure is mounted on a material with low lateral stiffness that results in a shift of the fundamental frequency of the structure away from the dominant frequencies of a seismic ground motion. An isolation system provides an additional means of energy dissipation and reduces the transmitted acceleration into the superstructure [2]. On the other hand, in the vicinity of active faults, the ground motions are considerably different with far-field ones. Near-field ground motions have a distinct pulse, in general, at the beginning of the seismogram, and their effects increase the long-period portion of the acceleration response spectrum. Forward directivity occurs where the fault rupture propagates with a velocity close to the shear-wave velocity. Fling step is characterized by a unidirectional large-amplitude velocity pulse and a monotonic step in the displacement time history [3]. Due to considerable effects of near-field earthquakes on building structures, this paper attempts to investigate the seismic behavior of base-isolated building frames under the effects of near-field ground motions using the nonlinear time history analyses (NLTHAs).

2- Design of base-isolated frames

First, the fixed-base structures were designed in accordance with the requirements of the ASCE7-10 and AISC341-10. They include 9 and 12-story steel moment-resisting frames. The structures were isolated at the base with the aid of different types of isolators. Three types of isolators (LRBs) with different protective levels were designed for each structural model. Isolators were designed in such a way that cover a wide range of period of isolation system. Isolators' stiffness for three different protection levels was chosen as follows: a) Hard isolators that cannot adequately protect the structure and limit it to collapse prevention in an intensity of 0.8 g (in this study); b) Normal isolators that keep the superstructure in the limit of the linear range and limit the maximum rotational ductility factors of the beams and columns for the design load combinations to a value of less than or equal to 1; c) Soft isolators that keep the superstructure mainly in the elastic region for different intensities [4].

For the protection level 2, the horizontal stiffness of isolators was selected by means of elastic analysis for the seismic design level and soil class D using the ASCE7-05 response spectrum. It was assumed that the behavior factor is equal to 1 (R_I=1). Such isolation systems may not be practically used but in all cases where the design base acceleration is exceeded, damage can be expected for the superstructure. The other two protection levels (i.e. hard and soft isolators) were produced artificially with a significant increase and decrease in the isolators stiffness, respectively, without any changes in the main properties of the isolators (Q, K_1/K_2) in which K_1 and K_2 are the elastic stiffness and post-yield stiffness of

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isolators, respectively, and Q is the characteristic strength of isolators.

3- Non-linear response history analysis

The Newmark average acceleration scheme (β=0.25 and γ=0.5) was used to conduct the NLRHA [5]. The NLRHA was carried out using three sets of near-field ground motions with forward directivity, fling step and no pulse characteristics as well as one set of far field ground motions. The ground motion records were chosen from the strong ground motion database of the Pacific Earthquake Engineering Research (PEER) Center (http://peer.berkeley.edu).

In order to define the Rayleigh damping matrix, a damping ratio of 5% was assumed for the first and third modes of vibration. Isolators' damping was considered independently as the hysteretic damping with the bilinear model of bearings. The non-linear behavior of the superstructures members was defined based on FEMA356 [6] with the assumption that the plastic hinges are formed at both ends of the members. For beams, the plastic hinges were defined considering the effect of bending moment about strong axis (M3), and for columns, they were defined considering the interaction of the axial force and bending moment (P-M3).

4- Conclusions

The results showed that the change in the stiffness of isolation system from hard type to soft and moderate types (that increases the damping and the period of the structure) reduces the seismic demands of the structure. Also, the story drifts of base-isolated building frames with soft isolator (more damping) are smaller than those with hard and moderate types for different values of pulse period (T_p). The sensitivity of the responses of base-isolated building frames with hard isolators (low damping) to pulse period is large. Ground motions with a long pulse period have a large effect on the displacements of the structures for the three isolation types. Figure 1 shows that the ground motions with different characteristics produce larger accelerations in structures with hard isolators than with normal and soft isolators.

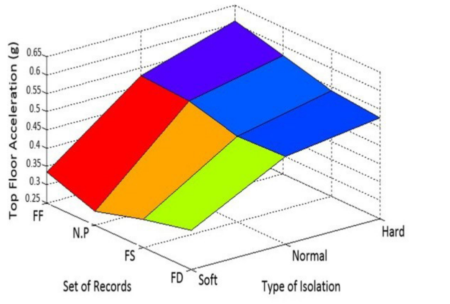

Figure 1. Top floor acceleration of the base-isolated 9-story frame under the influence of the four sets of ground motions

References

[1] F.Y. Cheng, H. Jiang, and K. Lou, Smart structures: Innovative systems for seismic response control, CRC Press, 2010.

[2] R. S. Jangid, Optimum lead–rubber isolation bearings for near-fault motions, Engineering structures, 29(10) (2007) 2503-2513.

[3] E. Kalkan, S.K. Kunnath, "Effects of fling step and forward directivity on seismic response of buildings, Earthquake Spectra, 22(2) (2006) 367-390.

[4] V. Kilar, and D. Koren, Simplified inelastic seismic analysis of base-isolated structures using the N2 method, Earthquake Engineering & Structural Dynamics, 39(9) (2009) 967-989.

[5] A.K. Chopra, Dynamics of structures: Theory and applications to earthquake engineering. Prentice-Hall, 2007.

[6] Building Seismic Safety Council (BSSC), Pre-standard commentary for the seismic rehabilitation of buildings, FEMA-356, Washington (DC): Federal Emergency Management Agency, 2000.

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