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The Effect of Site Seismic Hazard on Selection of a Retrofitting Method for a Deficient Reinforced Concrete Frame

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ABSTRACT: One aspect of Performance Based Earthquake Engineering (PBEE) is to allow comparison between different designs and retrofit solutions using estimation of collapse probability. To investigate this process, case study was performed on the weak RC frame that has been retrofitted with two different methods, e.g., brace and cylindrical friction damper. Models of case studies were defined in OpenSees software. Then 15 ground motions were selected and Incremental Dynamic Analysis (IDA) was conducted on models. The performances of buildings were evaluated by using a probabilistic analysis. The results show that the retrofit methods reduce the probability of exceeding of the limit states [1]IO and [2]CP. However, considering site-specific seismic hazard curve in which the reduction of structure period was included, the different results were obtained. In this study, although the damage probabilities for a specific hazard level for both retrofitting schemes were reduced, the collapse probability of the structure retrofitted with braces increased in comparison with the initial structure.

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1- Introduction

In many areas around the world, reinforced concrete (RC) buildings designed using the older codes should be retrofitted to withstand earthquake forces in compliance with modern design codes [1]. One of the most efficient systems for resisting lateral seismic loads is steel bracing systems. Although bracings reduce the lateral displacements through increasing lateral stiffness but the maximum axial forces in columns are increased [2], and then due to their buckling, lateral strength of structure would be suddenly decreased and the designed ductility of the structure would not be provided. Progress in science and technology provides new ways to develop new systems for controlling structural systems. The structural control systems, such as dissipating energy filters absorb the energy induced to the dynamic systems [3].
Performance-based Earthquake Engineering (PBEE) is a method for evaluating the seismic performance of structures. One of the important aspects of this method is to allow comparison between different retrofit solutions [4]. To investigate this process, case study was performed on a weak RC frame that has been retrofitted with two different methods, e.g., using braces and using Cylindrical Friction Dampers (CFD).

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1 Immediate Occupancy
2 Collapse Prevention

2- Methodology

Three frames are included in the analytical case studies. One is a deficient RC frame and two other frames are the original bare frame that has been retrofitted with braces and CFDs. Two-dimensional models of case studies were defined in OpenSees software and a set of 15 ground motions was selected and Incremental Dynamic Analysis (IDA) was conducted on the three models. Finally, by using a probabilistic analysis, comparison between retrofit schemes were done.

3- Main Contribution

Using PBEE methodology, the collapse probability of three mentioned frames was computed. The two retrofit schemes were compared with each other. Utilizing this process can aid to choose a proper scheme in the retrofitting program.

4- Results

The results of this study show that in order to retrofit a weak RC structure which was designed based on the older building code regulations, retrofitting with proposed methods significantly improve building performances in both limit states, that is more tangible for the IO performance level than CP. By comparing the buildings equipped with CFDs and braces, it can be seen that performance of the building retrofitted with CFD in IO level has similar performance to building retrofitted with braces, while in CP level, with increasing the intensity, friction dampers avoid the buckling of the braces and lead to a better performance in comparison with chevron bracing scheme (Figures 1 and 2).

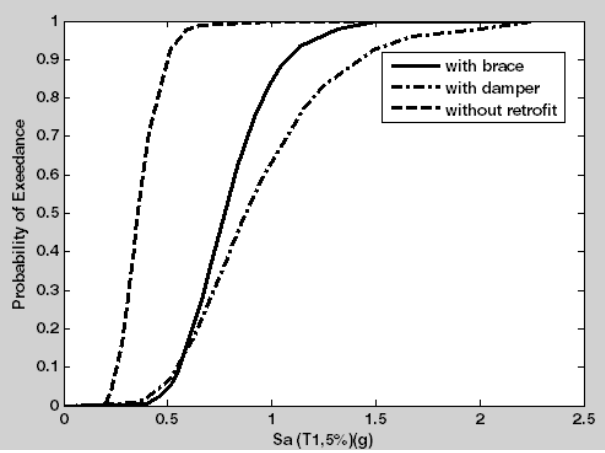

Figure 1. The fragility curves at IO limit state for frames

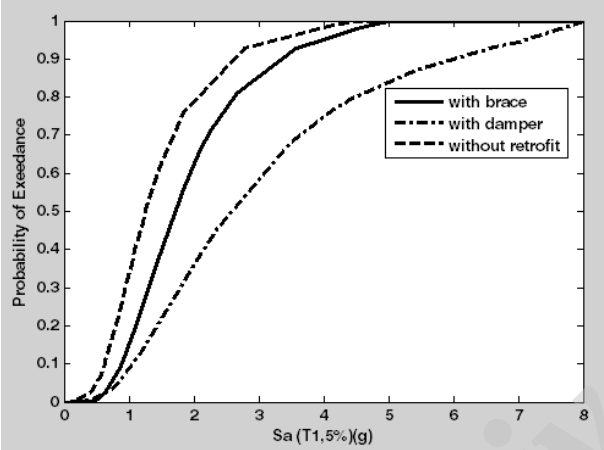

Figure 2. The fragility curves at CP limit state for frames

With considering site-specific seismic hazard curve in which the reduction of structure period was included, different results were obtained. Mean Annual Frequency (MAFs) of exceeding CP limit state are increased for frames retrofitted with bracings about 28-36 percent and decreased for frames retrofitted with CFDs about 22-23 percent, in comparison with the initial structure. Therefore, performance of the frame retrofitted with bracings at CP level is not satisfactory comparing with the original one.

Table1. MAF for frames

Variation of MAF (%)	Numerical Solution		Closed-Form Solution	
	IO	CP	IO	CP
With brace vs. without retrofit	-59.4	36.7	-59.1	28.4
with CFD vs. without retrofit	-59	-22.2	-60	-23
With CFD vs. with brace	0.88	-43	-4.28	-40

According to the analyses performed in this study it can be concluded that the use of bracings for the IO performance level and CFDs for the CP performance level in a retrofitting program of under studied deficient RC frame is preferred in terms of less MAF values.

It should be noted that at the IO performance level, increasing the lateral stiffness and at the CP performance level, developing dissipation of seismic energy is more effective.

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