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Probabilistic Seismic Vulnerability assessment of RC Frame Structures Retrofitted with Steel Jacketing

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ABSTRACT: A majority of Iranian residential buildings have Reinforced Concrete (RC) frame structures with intermediate ductility. Recent earthquakes have revealed major seismic deficiencies in these buildings, some of which led to catastrophic collapses and significant death tolls. Causes for the unsatisfactory performance include the absence of special seismic detailing of key structural elements, inadequate material and construction quality. Based on an extensive field investigation done by the authors on the short, mid-rise and high-rise Northern Iranian as-built structures having RC frames, in this study, reduced strength of concrete and also insufficient overlap length of column's longitudinal bars are considered as common structural deficiencies and then by considering probable uncertainties such as material and earthquake uncertainty, the seismic performance of considered buildings are developed via fragility curves based on probabilistic method. For generation of seismic fragility curves for as built and also retrofitted models, 3 dimensional analytical models analyzed based on Incremental Dynamic Analysis (IDA) in OpenSEES. The demand statistics in terms of maximum inter–story drift ratio are obtained for 20 sets of ground motion records and the capacity is determined according to the HAZUS-MH limit states and finally the corresponding fragility curves for four damage states are developed for as built and retrofitted models. The results represent the effect of the story numbers, structural deficiency and implemented retrofit strategy on the seismic vulnerability of this subclass of structures.

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1-Introduction

Confining reinforced concrete column in steel jackets is one of the effective methods to improve the earthquake resistant capacity [1]. Fragility curves is a statistical tool representing the probability of exceeding a given damage state (or performance) as a function of an engineering demand parameter that represents the ground motion (in this study is PGA) [2, 3].

2. Analytical Models

Three subclasses of Reinforced Concrete (RC) structures with three, five, and eight stories with same plans were considered. Designing of these structures were carried out according to Iranian Earthquake code termed standard 2800 (Third Edition) [4] and Iranian concrete national code [5]. In this buildings, reduced strength of concrete and also insufficient overlap length of column's longitudinal bars are considered as common structural deficiencies. The models of considered structures and behavior of nonlinear material that use in models are presented in Figures 1 to 3.

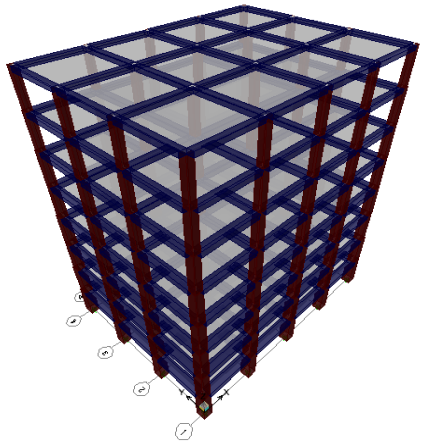

Figure 1. Sample of Eight-story 3D Model

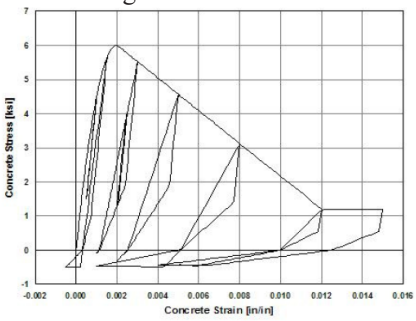

Figure 2. Concrete02 Material - Hysteretic Behavior [6]

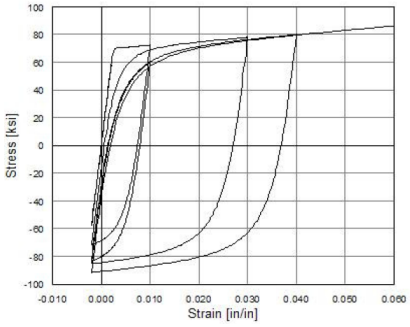

Figure 3. Steel02 Material - Hysteretic Behavior [6]

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Figures 4 and 5 show how the square RC columns are retrofitted by steel jacketing.

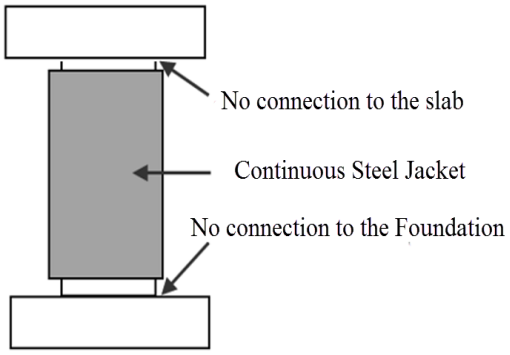

Figure 4. Modeling of Steel Jackets

Figure 5. Steel jacket retrofit of square RC columns

3-Results and Discussion

For generation of seismic fragility curves for as built and also retrofitted models, 3 dimensional analytical models analyzed based on Incremental Dynamic Analysis (IDA) in OpenSEES. Figures 6 to 8 represent the fragility curves of structures in the four levels of damage (slight, moderate, extensive, and complete).

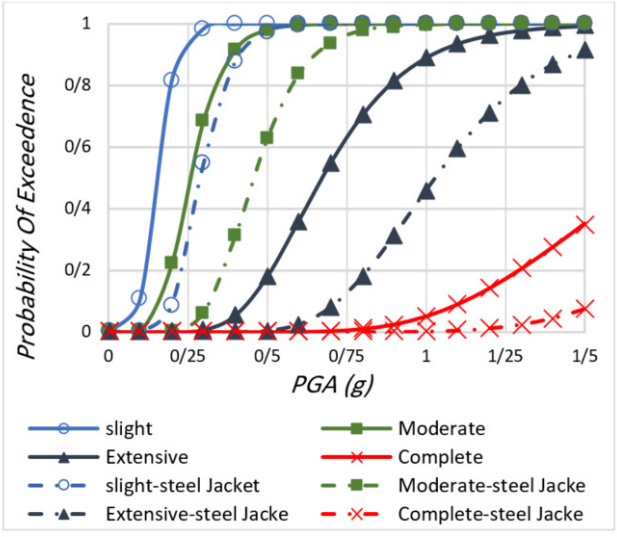

Figure 6. Fragility curves for 3-story building before and after retrofitting

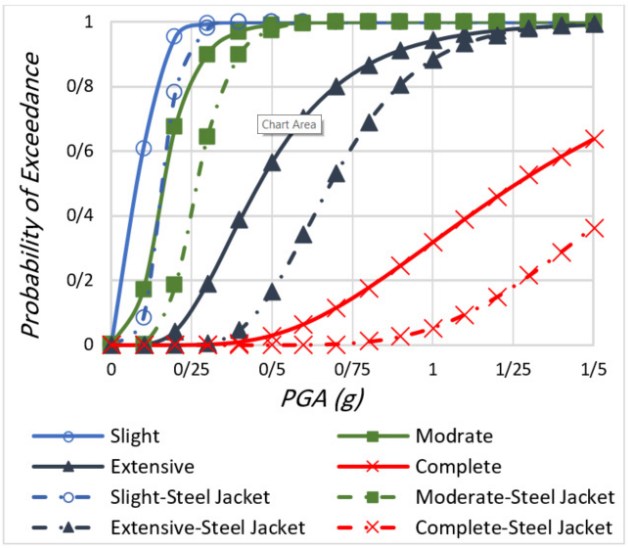

Figure 7. Fragility curves for 5-story building before and after retrofitting

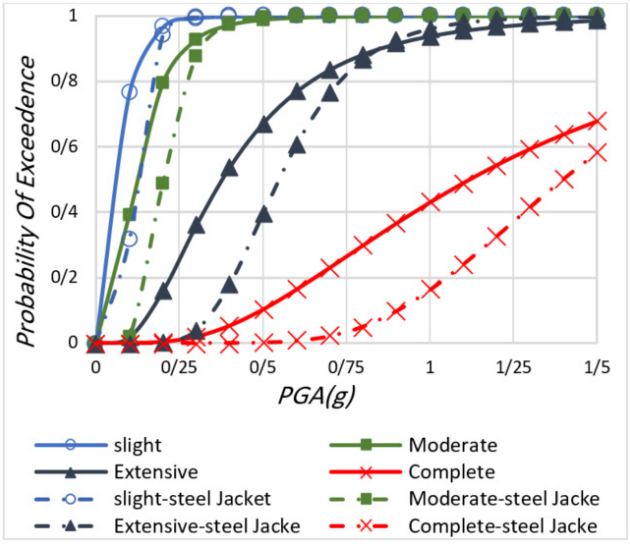

Figure 8. Fragility curves for 8-story building before and after retrofitting

4. Conclusions

According to fragility curves of three types of RC buildings with and without retrofitted by steel jacket, the following results were achieved. In general, with the increase in structure height, it's vulnerability increases in four damage states (slight, moderate, extensive and complete).

It can be seen from the figure curves that the average of medians of fragility for retrofitted buildings with 3, 5, and 8 story increased by 95, 74, 50 and 25 percent in four damage states of Slight, Moderate, Extensive and Complete, respectively.

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