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Probabilistic Seismic Assessment of RC Buildings Considering Soft and Extreme Soft Story irregularities Subjected to Main Shock-Aftershock Sequences

Hamed Kouhestanian, Hossein Pahlavan, Jalil Shafaei*, Mohammad Shamekhi Amiri

Faculty of Civil Engineering, Shahrood University of Technology, Shahrood, Iran

ABSTRACT: Recent Iranian earthquake damages like the damages caused by the Kermanshah earthquake revealed that RC buildings having soft-story irregularities experienced more seismic vulnerability. Moreover, earthquake aftershocks increased the seismic failures in past earthquake events. But they are not included in recent seismic design codes. In this article, for assessing the effects of soft-story irregularities and also the earthquake aftershocks, 3,5 and 8 story RC models having intermediate sway frames are designed and then modeled in OPENSEES and then IDA analysis is performed in order to produce the seismic fragility curves consistent with HAZUS definitions. The resulting seismic fragility curves revealed the influence of soft-story irregularities and also main shock-aftershock sequences on the vulnerability of considered RC models. By increasing the height of the RC structures, the effects of soft-story irregularities and the aftershocks decreased in the seismic vulnerability of the considered buildings.

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1- INTRODUCTION

A recent glimpse of contemporary Iran's history, such as the Bam earthquake, Manjil, Buinzahra, and recent Kermanshah earthquake, show that existing RC structures are highly vulnerable to earthquake effects, based on old regulations. Many RC buildings built in the country due to height difference about parking, as well as inappropriate use of Masonry frames, there are sudden changes in the story stiffness, which, due to the soft and Extreme soft story, lead to the vulnerability of the building The earthquake occurs when the earthquake occurs. Yin and Li developed a complex methodology to estimate the loss after earthquakes and applied it to the wood frames. Luco et al. proposed an incremental dynamic analysis (IDA) based numerical procedures to facilitate the probabilistic assessment for the increasing levels of damage states due to aftershocks [1]. Ryu et al. used the above procedures to generate the seismic fragility curves of reinforced concrete (RC) frame under repeated earthquake events. However, it should be noted that although the above studies have tackled the effects of aftershock in terms of seismic demands or fragility of specific structural models, the literature is limited. More research should be warranted to evaluate the effects of aftershock using different structural types and models [2].

2- PROPERTIES OF MODELS USED IN THIS RESEARCH

In this research, models of three, five, and eight stories of three-dimensional, Reinforced Concrete Moment-Resisting Frame, soft and Extreme soft-story have been used.

The specification of the model used is as follows:

- building is designed in a region with a high relative risk and the site of the construction site is assumed to be of type III.
- The height of the first story is for an irregular structure of soft and Extreme soft story of 3.7 and 6 meters, and the height of other stories is 3.2 meters.
- the concrete was found to have a compressive strength of 25 MPa and the reinforcing steel bar was found to have a yield stress of 400 MPa.
- Effect of confinement of transverse reinforcement on the cyclic behavior of concrete section was considered using equation was proposed by Mander et al. [3]. The application of using the methodology for considering the effect of confinement was previously proposed by Pahlavan et al [4] for Iranian in-filled RC frame structures.

3- SELECTION OF EARTHQUAKE ACCELERATION AND MAIN SHOCK AND AFTERSHOCK INTEGRATION

Determining the record of aftershock earthquakes is one

*Corresponding author's email: jshafaei@shahroodut.ac.ir

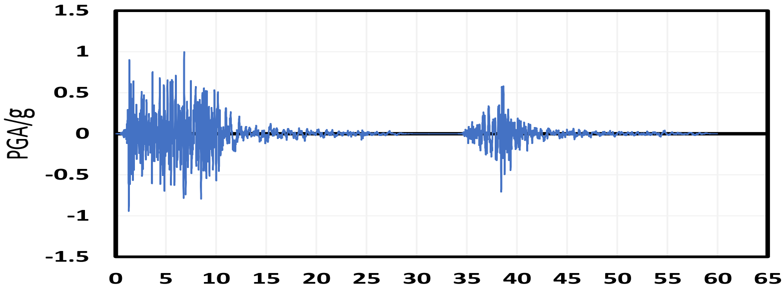
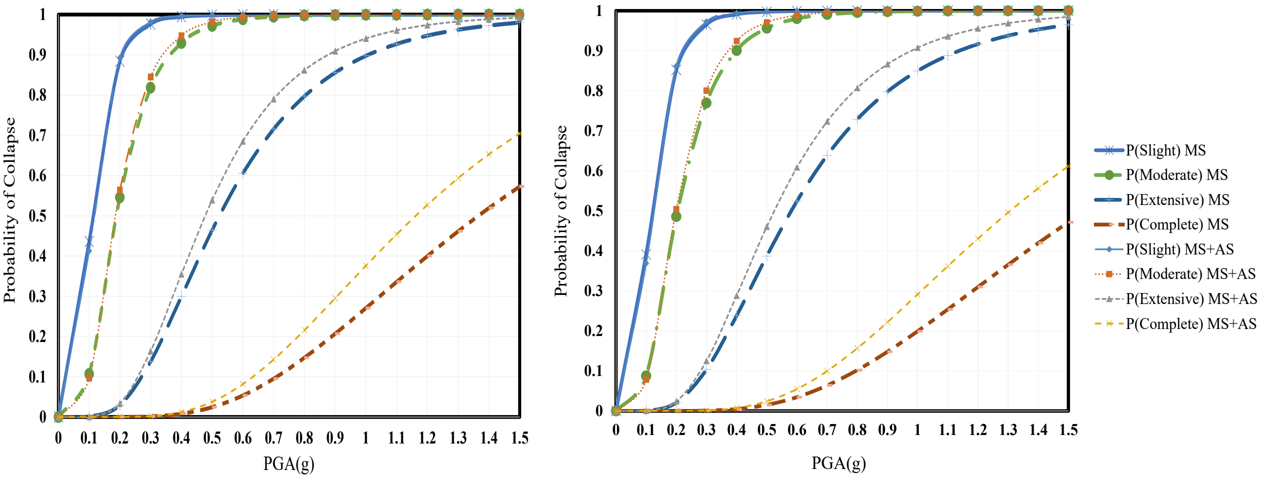


Fig. 1. Mammoth Lakes-Convict Creek Mainshock and Aftershock Scale Acceleration



(a) (b)

Fig. 2 Fragility curve of the 8-story model with (a) soft and (b) Extreme soft stoty under mainshock and aftersock sequence

of the most important steps in nonlinear dynamics analysis; Because the results of an increasing nonlinear dynamic analysis depend on the type of record. In this study, 20 earthquake records were selected based on the type of site's soil and according to the recommendations of Yu Lee and his colleagues under the following conditions from the peer site.[5]:

- The soil has a shear rate of 175-375 m / s.
- The magnitude of the seismic is at least 5.0.
- PGA is greater than 0.4g.

To simulate this research with the real world, the models were first subjected to earthquake acceleration and then the structural was suspended for 4 seconds until the permanent displacement of the earthquake remained, and the vibrations of the main earthquake would be stopped due to the damping, then Structural is placed under After-shock acceleration. In the new accelerated sequence, the Main earthquake merger, Sleep mode, and After-shock mode are created, and all new acceleration pulses are increased to a ratio and scaled to 1g.[6]

4- GENERATE AND PLOT THE FRAGILITY CURVE

Fragility curves determine the probability of passing through a specific failure level versus the seismicity parameters of the building. To generate the fragility curve, a probability distribution is used for engineering demand parameters that are derived from the IDA analysis. In this research, the distribution of the normal log is used. Each structure was analyzed once with 20 earthquake records from 0.1 g to 1.5 g and again under Earthquake-Aftershock-seismic sequence and from 0.1 g to 1.5 g. Then, the probability of structural failure was investigated using Openness software.

The fragility curves can be written according to equation (1).

$$P(:\leq D)=\Phi\left[\left(\frac{\mathrm{Ln}\left(S_d/S_c\right)}{\beta_{sd}}\right)\right] \tag{1}$$

In the above relation, p is the deflection state D (maximum displacement between classes), β_{sd} is the standard deviation logarithm, s_c is the mean value of the permissible gravity, is the average amount of seismic demand.

5- CONCLUSIONS

After analyzing the structures of reinforced concrete, three, five and eight stories with a soft, and Extreme soft story with different height, the results show that there is not much difference between the height difference for the slight and moderate failure levels, but in the Extensive level and The collapse of the effect of the height difference is significant.

Also, with the increase in the number of stories, the effect of the difference between the first story on two types of irregularly structured structures is less soft and Extreme soft of four-dimensional damage. Aftershock in structures with low elevation and low stories has a significant effect on all four levels of failure, while with increasing height and number of stories, this effect has been reduced to all levels of deterioration such that it will be negligible in high-rise structures.

By comparing the fragility curves for three, five, and eight class models under the influence of single earthquake and sequencing of the earthquake and post-earthquake, it can be concluded that post-shrinkage in low PGAs has an effect on increasing the damage of structure but with increasing earthquake acceleration, post-shock increases the number of failure levels.

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