Probabilistic seismic Assessment of RC buildings with considering the effect of soil structure interaction

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ABSTRACT

In this paper, the seismic response of base-isolated and fixed-base concrete structures with soil-structure-interaction effect was investigated. The structures with 4, 8, and 12 stories with lead rubber bearing isolators on three types of soils including soft, medium, and firm soils as well as on rigid foundation modeled using OpenSees software v 2.5.0. The ACI 318-02 code was used to design of RC intermediate moment frames. The incremental dynamic analysis was performed to determine the structural response under six near field and six far-field earthquakes recorded with the same seismic parameters but with different stations. The inter-story drift ratio and failure probability for each level of damage (slight, moderate, extensive and complete) were calculated and the fragility curves for maximum inter-story drift in different levels of PGA were drawn. The results indicated that considering the soil-structure-interaction decreased the structural damage on both isolated and fixed base structures. Softening the soil under isolated structures resulted in increasing the median fragility acceleration in each level of damage. Furthermore, considering the soil-structure-interaction effect in the low-rise to medium-rise structures (4 and 8 story buildings) has a more significant effect on median fragility accelerations than high-rise buildings. While, the effect of the base shear on the 12-story frame was more considerable.

KEYWORDS

RC moment frame, IDA analysis, LRB isolator, Fragility curve, Far field, Near field.

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1. Introduction

Base isolation is a seismic-resistant approach designed in order to reducing the seismic demands instead of increasing the capacity of structural members. This technology improves the behavior of structures during large earthquakes, mainly remain in the elastic range [1-3].

In seismic design of buildings using isolators, it is often assumed that the structures are on rigid foundations, thus the effect of soil-structure interaction is neglected. It seems reasonable to some researchers [4,5], but there are studies believe that assuming the rigid foundation is not always reliable [6,7]. So, many studies have been done on isolators and the effect of soil-structure interaction. However, more comprehensive studies are needed to study the behavior of different soils and different isolated structures with a large number of scaled records in near-field and far-field earthquakes.

In this paper, the seismic response of base-isolated and fixed-base concrete moment frame structures with soil-structure-interaction (SSI) effect was investigated. For this purpose, three models with four-, eight- and twelve-story 2-D frames with and without LRB isolators on rigid, soft, medium and hard soils were modeled in OpenSees v2.5.0 software. Six near-field records and six far-field records with the same components but different stations were selected, scaled in 15 steps, and applied to each of the modeled frames (Figure 1). Finally, by receiving the relevant answers and presenting them on the incremental dynamic analysis curves, fragility curves and etc. the necessary comparisons were performed.

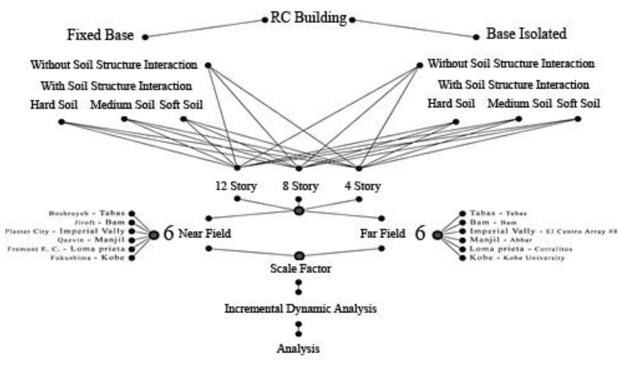

Figure 1. Research chart for 4, 8 and 12 story buildings with and without considering the interaction of soil and structures

2. Methodology

In this study, 15 models of 4, 8 and 12 story concrete frames with and without SSI were modeled in OpenSees software (Figure 2). Isolators designed for different structures [8] and the Elastomeric Bearing element is used in this paper to model a lead Rubber Bearing (LRB) isolator in OpenSees software [9].

In order to consider the effect of soil-structure interaction, the Beam on Nonlinear Winkler Foundation (BNWF) based on Raychowdhury work has been used.

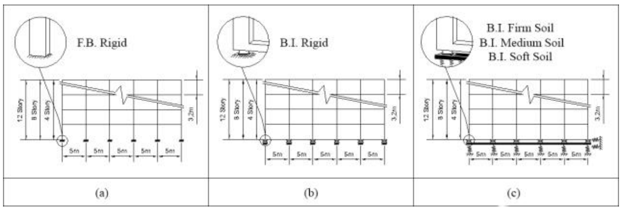

Figure 2. Frames modeled in this study, a) fixed base without SSI, b) isolated base without SSI, and c) Isolated base with SSI

Six near-field records and six far-field records that had the same components but different stations were selected, then each of them was scaled in 15 steps and individually applied to 4, 8 and 12 frames.

Verification in this study has been done in two ways. First, by comparing the analytical 1st modal period of 4, 8 and 12 story frames obtained from Sap2000 software with the period obtained from OpenSees software (Table 1), the accuracy of the modeling in OpenSees software was investigated.

Table 1. Comparison of the 1st modal period of modeled Frames

Period (s)			Model
Difference	Sap2000	OpenSees	
11%	0.792	0.669	4 Story
6%	1.338	1.26	8 Story
8%	1.94	1.77	12 Story

By comparing the difference in period obtained from the two softwares, it can be concluded that the modeling has been done correctly.

In the second part of validation, the results obtained from OpenSees software are compared with the experimental results obtained and reported by Frank et. Al [10]. Comparison of the results shows the acceptable accuracy of the modeling with the software (Figure 3).

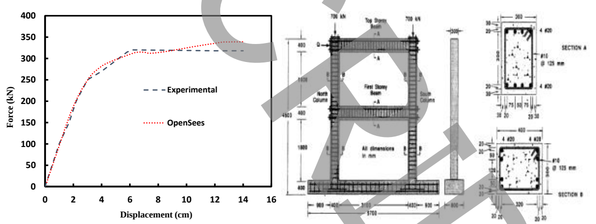

Figure 3. Comparison of laboratory concrete frame results and frame that modeled in OpenSees software [10]

3. Results and Discussion

Based on fragility curves shown in Figures 4-6, probability of failure in isolated structures is more than the fixed-base structures at peak ground accelerations (PGA). However, as the damage increases and the soil changes from hard to soft, this increase in PGA is continued. In other words, considering the interaction of soil and structure has reduced the damages to structures at the same accelerations.

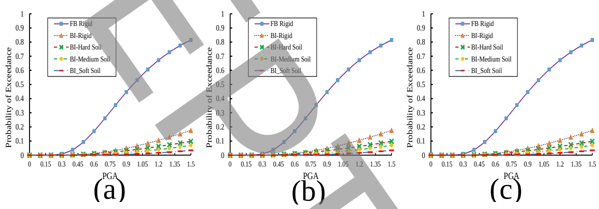

Figure 4. Fragility curves for 4-story structures with and without SSI in failure states a) high, b) medium, c) low

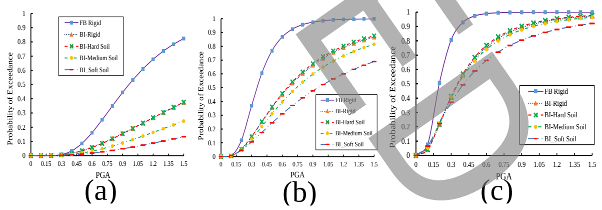

Figure 5. Fragility curves for 8-story structures with and without SSI in failure states a) high, b) medium, c) low

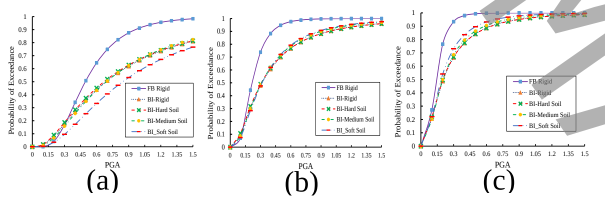

Figure 6. Fragility curves for 12-story structures with and without SSI in, a) high, b) medium, and c) low failure states

As the soil softens at all levels of damage, the acceleration associated with the median fragility increases and the drift ratio corresponding to the median fragility in all cases was higher for near field earthquakes than far field earthquakes. This can be related to shock effect in the structures due to near field earthquakes.

Isolated structures have much higher acceleration in the median fragility than structures with a fixed base, which indicates a reduction in the vulnerability of isolated structures.

4. Conclusions

According to the obtained results and comparisons, it can be said that it is necessary to consider the effect of soil-structure interaction on isolated structures. Moreover, the hard and medium soils are introduced as the best type of soil for isolators.

5. References

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