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Seismic Behavior Assessment of RC Precast Frame Damaged in Bojnord Earthquake 2017 Considering Soil-Structure Interaction Effects

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ABSTRACT: Experiences of previous earthquakes show the effects of soil-structure interaction and behavior of beam-column connections on the seismic behavior of the building structures. In this research, seismic vulnerability assessment of RC precast Frames is investigated by consideration of the effect of soil-structure interaction and nonlinear behavior of beam-column connections. The RC precast building represented in this study, damaged in the Bojnord earthquake 2017 and located on the soil type II of Iranian seismic design code. The soil-structure interaction is modeled using the Beam-on-Nonlinear-Winkler foundation. In this procedure, an array of vertical q–z springs are used to capture vertical and rotational resistance of the foundation, while two springs, namely p–x and t–x, are placed horizontally to capture the passive and sliding resistance of the foundation, respectively. The seismic vulnerability and performance of RC precast frames are evaluated using nonlinear static pushover, nonlinear dynamic time-history analyses, and incremental dynamic analyses (IDA). The numerical models are developed using OpenSees software by consideration of the nonlinear behavior of the beam-column joints. The numerical results showed the significant role of soil-structure interaction and beam-column connections on the seismic vulnerability and performance of RC precast buildings. In fact, seismic vulnerability of RC precast buildings was increased by considering soil-structure interaction and beam-column connections effects.

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1. INTRODUCTION

The effects of soil-structure interactions are generally not significant in the structure with rigid bases, while the nonlinear behavior of soil-structure interaction (SSI) causes various changes in the seismic response of structures with flexible bases [1]. The considered precast buildings consist of a precast column with corbel and semi-precast beams. The connectivity between the beam bottom and the corbel top is established by welding two steel plates and two threaded bars of the top beam passed through the stirrups of the beam and two holes in the column. Then, expandable grout is used to fill the space of the connection and two holes in the column. One of the important points in the implementation of precast concrete structures is how to connect the precast elements of the beam to the column, which will have a significant effect on the seismic behavior of these structures. So, in this paper, the effect of soil-structure interaction and beam-column connections are studied to seismic vulnerability assessment of RC precast Frames. The precast concrete building represented in this study referred to the 5-story precast building (Deesman) damaged during the Bojnord earthquake in Iran on 13th May 2017.

2. METHODOLOGY

For nonlinear static and dynamic analyses of the buildings, a 2D model was created in Opensees software. The displacement-base beam-column element with fiber section has been used for the modeling of beams and columns. Concrete01 (no tensile strength) and Steel02 were used to define concrete and steel materials. In addition, confinement of the concrete in columns was considered according to the relationships provided by Mander *et al.* [2]. In this study, the nonlinear behavior of precast beam-column joints was simulated by a nonlinear model proposed by Adibi *et al.* [3]. Due to the cracking pattern observed in the substructure, it can be assumed that the nonlinear behavior of the section at the end of the beams controls the nonlinear behavior of the substructure. Therefore, a nonlinear rotational spring is considered at the end of the beam at the connection to the column for introducing the nonlinear behavior of the substructure. Characteristics of the spring are largely dependent on the implementation details of the precast joints. The soil-structure interaction is modeled using the Beam-on-Nonlinear-Winkler foundation. In this procedure, an array of vertical q–z springs is used to capture vertical and rotational resistance of the foundation, while two springs, namely p–x

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Table 1. Details of soil parameters

Soil type	C (kpa)	ϕ	υ	γ (gr/cm^3)	q_{ult} (kg/cm^2)
II	0	29	0.25	1.99	5.048

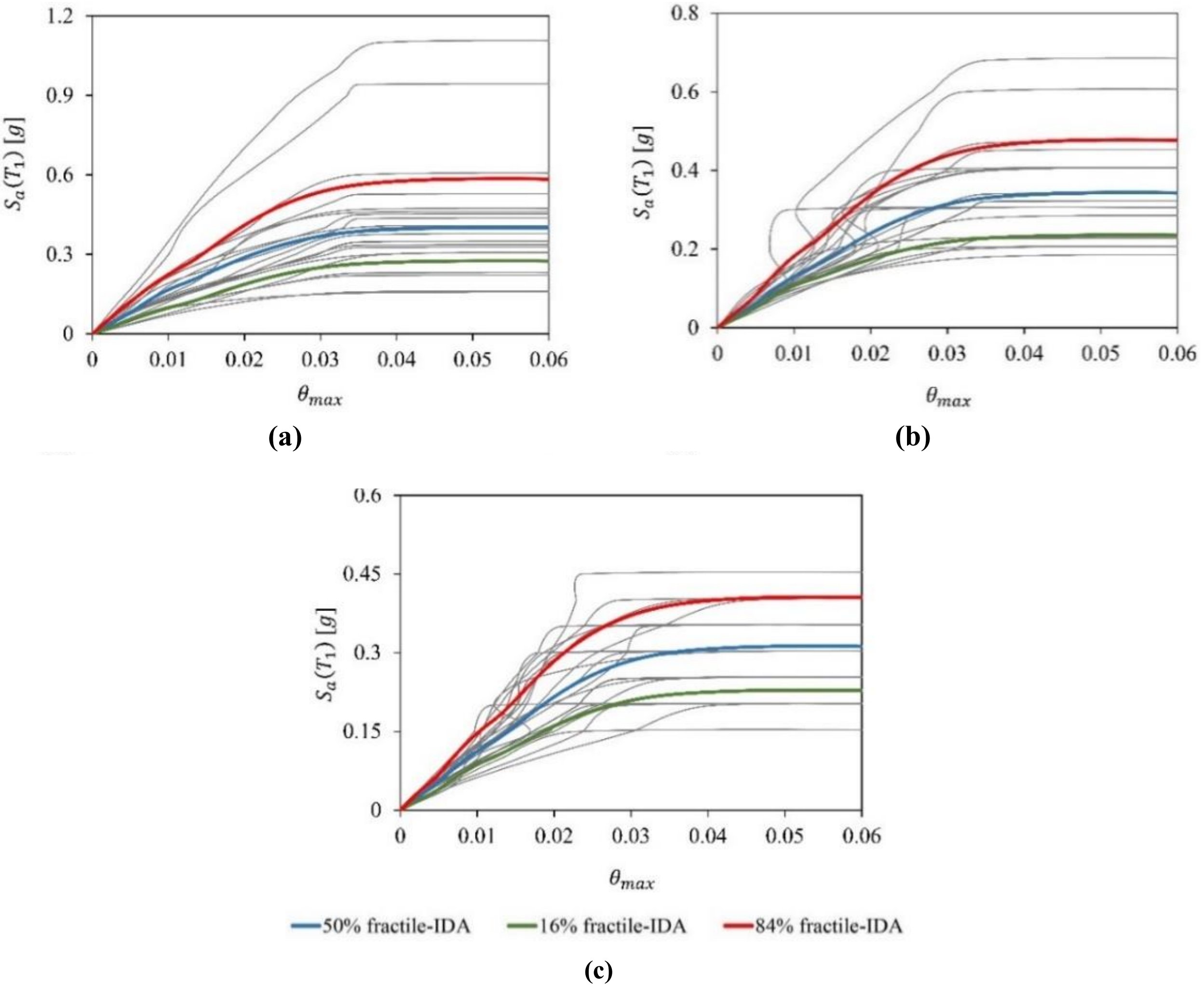

Fig. 1. Results of IDA for (a) Without SSI & BCC, (b) Without SSI & with BCC, and (c) With SSI & BCC

and t–x, are placed horizontally to capture the passive and sliding resistance of the foundation, respectively [4]. The geotechnical design parameters are presented in Table 1.

3. RESULTS AND DISCUSSION

Incremental dynamic analyses were conducted to develop fragility curves for various damage states. In IDA, a structural model is subjected to a set of ground motion records, scaled to different levels of intensity to describe the structural behavior from elastic to collapse [5]. The HAZUS-MH-MR-5 provisions were used to determine damage limit states (maximum inter-story-drift ratio). Fragility curves provide a probabilistic framework to estimate the likelihood of seismic demand exceeding pre-defined limit-states, i.e., slight, moderate, extensive, and complete collapse. Fragility curves are also derived as a function of "first-mode" spectral acceleration, *Sa* (T1, 5%), for the slight- complete collapse prevention limit state based on the statistical exploitation of the IDA results (Fig. 2) of the given structural systems (Fig. 3). Without considering soil-structure interaction (without SSI) and beam-column connections (without BCC), the median spectral acceleration amount was 0.0409g, 0.07245g, 0.1925g, 0.3865g, for slight, moderate, extensive, and complete damage, respectively. By considering beam-

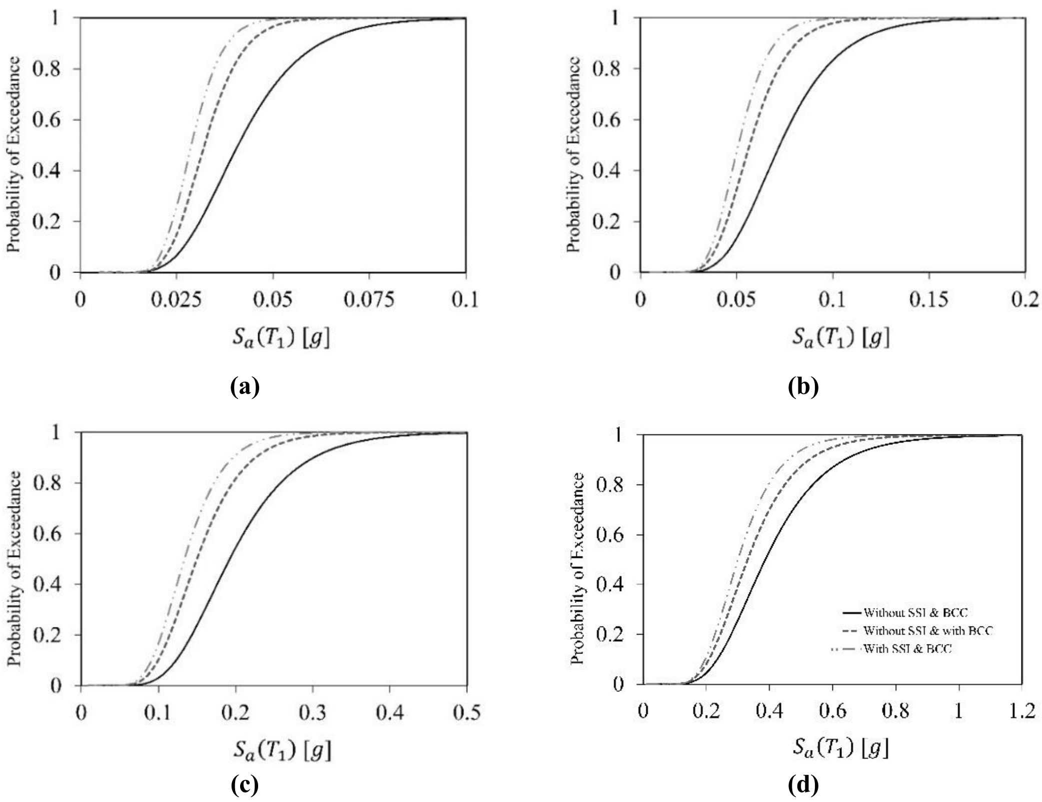

Fig. 2. Fragility curves for (a) slight, (b) moderate, (c) extensive, and (d) complete damage

column connections (with BCC) and without considering soil-structure interaction (without SSI) the median spectral acceleration amount was 0.03215g, 0.05675g, 0.15g, 0.3305g, for slight, moderate, extensive, and complete damage, respectively. By considering soil-structure interaction (with SSI) and beam-column connections (with BCC) the median spectral acceleration amount was 0.028g, 0.0509g, 0.13385g, 0.3g, for slight, moderate, extensive, and complete damage, respectively.

4. CONCLUSION

By considering soil-structure interaction (SSI) and beam-column connections (BCC) the seismic vulnerability of precast frames is increased at four hazard levels (slight, moderate, extensive, and complete). The results emphasized the necessity of consideration of SSI and BCC effects for safe structural design.

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