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Probabilistic Evaluation of Seismic Performance of Moment Resisting Steel Frames with and without Masonry Infill on Rigid and Flexible Floor

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ABSTRACT: Examination of the damage caused by past earthquakes, such as the Kermanshah earthquake, confirms that infilled-frame buildings, which were built on soft soil, experienced more damage than these buildings on site with hard soil. One reason for this damage is ignorance of the effects of masonry infill on the behavior of the structure, despite the recommendations of seismic codes. Therefore, in this research, the effect of the presence or absence of masonry infills on the seismic performance of steel moment-resisting frames with considering the effect of soil-structure interaction has been investigated. In this regard, incremental nonlinear dynamic analyzes were performed on two-dimensional frames with 3, 6, 9, 12, 15, and 20 stories and three bays, which were designed in soil type B o based on Eurocode-8. For this purpose, 21 far-field ground motions were selected according to the FEMA-P695 and time history analyses were performed in SeismoStruct. Also, the effects of soil-structure interaction on both rigid and flexible substrates were considered. Then, probabilistic evaluation of the frames was performed by obtaining the seismic fragility curves in immediate occupancy (IO), life safety (LS), and collapse prevention (CP) performance levels. The results showed that the presence of infill panels reduces the vulnerability of structures, especially by increasing the frame height. The spectral acceleration required to create collapse prevention performance increases from 1.2 to 3 times. However, considering the effects of soil-structure interaction in the estimation of structural capacity is more reliable and leads to the more realistic capacity estimation of structures.

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1- Introduction

Experimental observations in previous earthquakes have shown that the presence of infill increases lateral stiffness and as a result, the structure will have a different response to ground stimuli. However, despite the emphasis of seismic regulations on the effects of the interaction of non-structural components that prevent the movement of structural members during an earthquake, in practice, only the periodicity of the structure due to the presence of infill in the design routine is taken into account. Obviously, given the variety of infilled frames, the type of infill and how they are arranged, simply doing so in estimating the behavior of the structure is not without ambiguity, and special criteria must be considered for the actual performance of the various infilled frames. Although ignoring the effect of infill from the point of view of strength can be reassuring in terms of the extra strength it creates in the structure, the experience of recent earthquakes has shown that ignoring the effects of infill will impair the performance of the structure. One of the main causes of this phenomenon is the increase in frame stiffness due to the presence of infill, which causes the frame to absorb a larger share of lateral force. Fracture and disintegration of the frame, For example, in previous earthquakes, such as the Sar-e-Pol-e-Zahab earthquake, most buildings designed and built by engineers were severely damaged due to a lack of attention to the negative effects of the walls [1].

Despite many studies on the effect of interframes as well as the effects of soil-structure interaction on seismic performance and response of structures to earthquakes separately in the technical literature, limited studies of both infill and soil-structure interactions have been studied simultaneously. Including Tavakoli and Moridi [2], the simultaneous effects of soil-structure interaction and interlayer of building materials in steel flexural frames are studied. They concluded that reducing soil shear velocity increases the effects of soil-structure interaction on nonlinear structure. In addition to the limited study, the experience of Sarpol-e-Zahab earthquake in 2018 showed that the simultaneous effects between the frame and the soil-structure interaction are significant [2]. In this study, the probabilistic effect of infilled frames on the seismic behavior of steel moment resisting frames has been investigated by considering the soil-structure interaction. For

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this purpose, two-dimensional steel moment frames with 3, 6, 9, 12, 15 and 20 stories with and without interlayers of building materials and also with and without the effect of soil-structure interaction were analyzed by nonlinear incremental dynamic analysis (IDA). Then, by obtaining fragility curves, probabilistic evaluation of structural performance was performed. In this regard, for modeling infilled frames, Crisafulli multi-strut method was used in SeismoStruct software [3, 4] and to consider the effects of soil-structure interaction, the method was used. Spring equivalent hardness (Cone method) Conan software was used

2- Methodology

In this research, the two-dimensional bending steel frames proposed in the article by Dimplus et al. [5] have been used. These frames have 3 openings with a length of 5 meters and have three to twenty stories, the height of the stories is 3 meters, which is schematically shown in Figure 1. It should be noted that the design of these frames is based on Euro code 8 (EC8) and the maximum ground acceleration (PGA) is 0.36 g and soil type B (based on EC8) [25] is considered. 21 far-field ground motion were selected according to FEMA P695 [6] in type C and D soils according to NEHRP [7, 8]. For modeling infills, the equivalent diagonal strut method proposed by Chrysafulli et al. [9] and Chrysafulli and Atel [10] has been used. This model is available in SeismoStruct software.

There are different methods for analyzing the effect of soil-structure interaction such as the finite element method, boundary element method, hybrid or hybrid method and substructure method [6, 11]. Cone method The Wolf original method, which is one of the types of substructure methods, was selected for building structures due to the consideration of soil behavior in the linear area, low cost, simplicity and acceptable engineering accuracy [32, 33]. This method considers the interaction of soil and foundation with the idealization of soil in the form of incompletely elastic cones. The cone model can be used to analyze translational movements (vertical and horizontal) and rotational movements (cradle and torsion). Cone models can be used for a variety of structures with general characteristics of being layered and buried, taking into account all degrees of freedom. The indirect conical method for applying soil-structure interaction considers modeling the soil dynamic system with a defective semi-infinite conical rod with a vertical axis.

Two-dimensional steel moment frames with 3, 6, 9, 12, 15 and 20 stories with and without interlayers of building materials and also with and without the effect of soil-structure interaction were analyzed by nonlinear incremental dynamic analysis (IDA). Then, by obtaining fragility curves, probabilistic evaluation of structural performance was performed. In this regard, for modeling infilled frames, Crisafulli multi-strut method was used in SeismoStruct software [12] and to consider the effects of soil-structure interaction, the method was used. Spring equivalent hardness (Cone method) Conan software was used

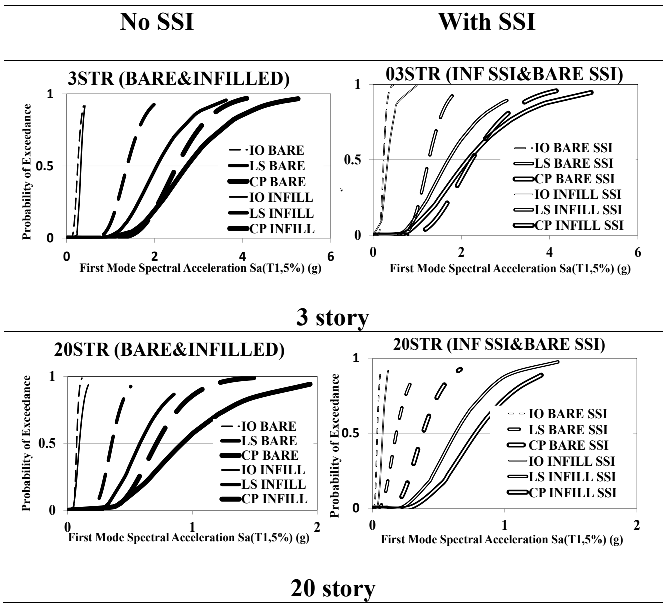

Fig. 1. Comparison of structural fragility curves of 3 and 20-story infilled and bare frames

3- Results and Discussion

Fragility curves related to structures with and without infill of three to twenty stories can be seen in two cases with and without considering the effect of soil-structure interaction at three functional levels (IO, LS, CP). Considering the three-story structures, considering the CP performance level, it is clear that the infilled frame without SSI passes the CP performance level at the spectral acceleration of the first mode equal to 5.3g. This is while considering the effect of soil-structure interaction; this spectral acceleration is reduced by 5.56g. It is worth noting that in a 3-floor bare frame, consideration or disregard for SSI has no significant effect on CP performance overruns. The same process applies to bare 6 and 9-story frames. The effect of considering and not considering the effect of soil-structure interaction varies for 12- to 20-story infilled frames to estimate the permeability of the CP performance level. Failure to consider, Failure to consider SSI is contrary to the assurance direction and leads to an inaccurate estimate of the capacity of the infilled frame structure to exceed the CP performance level. This effect is still maintained by increasing the height of the floors, so that in the middle floor of 20 floors, considering the effects of SSI in estimating the occurrence of CP performance compared to the state without SSI by 22% is in the opposite direction. For instance, the fragility curves of 3 and 20 story frame are depicted in Figure1.

the maximum effect of the infill is in the 9-story frame (about 3.5 times the CP performance level). And as the height increases, the effect of the infilled frames on the frame capacity will decrease (1.37 times in a 20-story frame at the CP performance level). While considering the effects of soil-structure interaction, the effect of infilled frame on the capacity of the structure will increase with increasing height. According to the third and fourth columns, it can be concluded that in both cases of infilled frame and bare frame, in general, considering the effects of soil-structure interaction has led to a realistic estimate of the capacity of the structure. In fact, disregarding SSI is in the opposite of reassurance.

4- Conclusion

The presence of infill walls increases the stiffness and strength of the structure, which depends on considering the effects of soil-structure interaction. In low-height infilled frames, considering the soil-structure interaction is more reliable. So that in the 3-story infilled frame, the spectral acceleration that causes CP performance is increased from 5.30g by considering the effects of soil-structure interaction to 5.56g in case of soil-structure interaction. However, by increasing the height of the structure, considering the soil-structure interaction makes a more realistic estimate of the behavior of the structure; in fact, disregarding SSI is the opposite of reliability. According to the obtained results, the most mentioned effect was observed in the 15-story frame, so the effects of soil-structure interaction are considered. The CP performance level occurred at 2.61g spectral acceleration and if SSI was not considered, it is observed at 3.81 g spectral acceleration (45% more unrealistic estimate). The mentioned effect is less by increasing the number of floors, so that in the 20-story frame, the amount of difference between amount of Sa(T1) caused CP performance in the frames with and without SSI is reduced. It was also found that considering the effects of soil-structure interaction in the short height bare frames can be neglected. However, in fifteen- and twenty-story bare frames, considering soil-structure interaction is reliable. For example, in 20-story bare frame, the spectral acceleration intensity required for the LS performance level is 0.95g, whereas it is reduced to 0.48g when the soil-structure interaction is considered.

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