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Evaluation of Seismic fragility of infilled frames subject to mainshock/aftershock sequences

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ABSTRACT: The purpose of this paper is to assess the seismic fragility and residual capacity of the reinforced concrete frame (RC) with masonry infills subject to mainshock/aftershock sequences in the far- and near-fields. In conventional incremental dynamic analysis (IDA), only the effect of the main shock is considered in the analysis, while the double incremental dynamic analysis (D-IDA) method which is used in this paper, considers the aftershock effects. Double incremental dynamic analysis approach is used, based on the combination of the mainshock(MS) at different intensities with a set of aftershocks (AS) scaled in amplitude with respect to peak ground. In this study, 20 near-field records and 20 far-field records were selected. In each analysis, a same record has been used for the main shock and after shock. The fragility curves of the intact and pre-damaged frames have been prepared for the records using fiber modeling in OpenSees software. Also, based on the results obtained from the incremental dynamic analysis, the frame residual capacity diagrams are defined and the infilled frame response is compared with the bare frame at different intensities of the main shock. According to the results obtained for infilled, the seismic fragility of the reinforced concrete frame is reduced due to the mainshock and aftershock. Also, the damages and losses economic of the structure under moderate earthquakes are reduced. According to the fragility curves, when only 100% collapse occurs in the bare frame, the probability of the frame collapsing with the infill wall at the same intensity as PGA (maximum ground acceleration) for near- and far-field earthquakes records is significantly reduced.

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1- Introduction

Due to the variable behavior of infilled frame and the methods of designing and modeling, many studies have been conducted in the past decades on the effects of infills in the frames. Dolsk and Fajfar[1] presented a relationship between displacement demand and seismic intensity for the evaluation of infilled concrete frames. Mondal et al.[2] applied the effect of openings by the reduction factor. Mainshocks (MS) can cause many aftershocks (AS). In this regard, Di Trapani et al. [3] investigated the influence of infilled frames on seismic fragility of RC structures under the sequence of MS/AS using the proposed double incremental dynamic analysis (D-IDA) method. The results of Di Trapani et al. [4] research on the 4-storey structure showed that masonry infills provide additional capacity to resist MS and AS ground motions. Yaghmaei et al. [5] investigated the influence of sequential earthquakes on the fragility curves for different damage states and showed that the well-known Omori's law could be considered a suitable tool for after shocks generation.

The amount of damage caused by the earthquake depends on many factors such as fault location, soil type and earthquake record characteristics as well as dynamic properties of the structure. Therefore, in this paper, the effect of near- and far-field records as well as the presence of aftershocks in the behavior of bare frame and infilled frame have been studied using standard and double incremental dynamic analysis. A 3-storey RC frame has been selected for numerical simulations.Results provide fragility curves of bare and infilled frame with different levels of MS intensity. Residual capacity and AS loss diagrams, illustrating the reduction of median collapse intensity as a function of MS intensity, are finally provided for bare and infilled frames for far- and near-field records.

2- Material and Method

2- 1- Description of Frames

A 2DRC frame with 3-storey and 3-bays has been investigated in this study. Lengths of bays are equal to 5.5 m and story heights are 3 m except 3.5 m for the first story. The infilled frame was arranged with clay hollow masonry blocks having a thickness of 17 cm with an existence of 33% opening. To consider the effect of existing openings, New Zealand code [6] equation was used, which the reduction factor equals 0.5 when there is 33% opening in the infilled

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Table 1. Strength and strain of concrete fiber section

Core	f_{cc0} (MPa) 28	ε_{cc0} 0.0024	f_{ccu} (MPa) 5.6	ε_{ccu} 0.015
Cover	f_{c0} (MPa) 24	ε_{c0} 0.002	f_{cu} (MPa) 4.8	ε_{cu} 0.005
Cover of Beam from each edge of the section				4.0 cm
Cover of Column from each edge of the section				4.5 cm

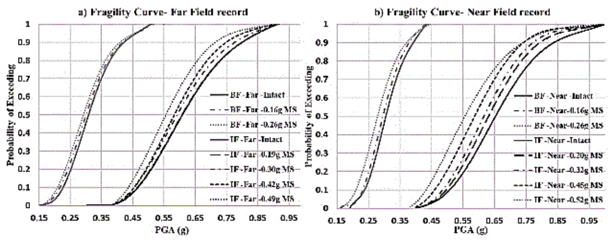

Fig. 1. Intact and aftershock fragility curves of the bare and infilled frame under a) Far-field; b) Near-field earthquake

frame. The lateral force resisting system is an intermediate moment frame and the type of soil is considered as II. Dead and live loadsof stories were considered 600 kg/m^2 and 200 kg/m^2, respectively. These parameters were considered 550 kg/m^2 and 150 kg/m^2, respectively, for the roof story. Dead load was considered 100 kg/m^2 for 17cm thick walls. The Concrete02 model was used for concrete fibers. Effects of concrete confinement are considered by Mander et al. [7] (see Table 1). Parameters used for concrete in tensions were ft=2.0 MPa (tensile strength) and Et= 1500 MPa (tension softening stiffness). Steel rebars were modeled as spread layers with the Steel02 material model. The elastic Young's modulus was Es= 210,000, while the hardening ratio was b=0.01.

In this paper, the masonry infill walls are modeled as an equivalent compressive strut. This strut is diagonal and connects the opposite joint of the frames with a length equal to the diameter and the width 0.2 times of frame diameter. The hysteretic behavior of the struts is considered by the parameter λ, which regulates the ratio between elastic and inelastic slopes of the unloading branches. The parameter λ is set equal to 0.07 for the equivalents struts and 0.1 for the concrete elements.

2- 2- Research Methodology

Incremental dynamic analysis is generally thought to assess undamaged structures undergoing a seismic event for the first time. The standard IDA procedure is modified by performing a double incremental dynamic analysis in order to consider different MS/AS combinations. The steps

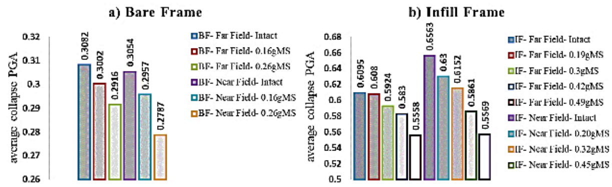

Fig. 2. Medium seismic fragility of the intact and damaged frame a) Bare frame; b) Infilled frame (IF)

to carry out D-IDA provide first defining ground motions as an assemblage of two signals, namely the MS and the AS, interspersed with a decay time sufficient to bring the structure back to static condition. MS and AS ground motions are taken from the same set of spectrum compatible accelerograms. Incremental dynamic analysis is performed using a MS ground motion having fixed intensity, each time combined with Aftershocks scaled in amplitude. IDAs are then repeated by changing the MS intensity and associating the same set of scaled AS ground motions. The double scaling of both MSand Aftershocks allows deriving fragility curves depending on MS intensity, and can be used to define residual capacity diagrams reporting the average residual capacity of a structure as a function of MS intensity.

3- Results and Discussion

Based on Figure 1, the fragility curves of the infilled frames are significantly shifted to the right for far- and near-field earthquake records which confirms the significant reduction of seismic fragility due to the presence of infills.

In Figure 2, the medium seismic fragility curves for intact and pre-damaged frames for bare and infilled frames are compared only under far and nearfield earthquake records. It is observed that for the bare frame, the structure collapses faster under near-field earthquakes. It can be observed that the behavior of infilled frame is different against nearfield earthquakes so that it collapses later than far field earthquakes. This issue can be related to the different frequency content in the near and far field earthquakes. In fact, as the system of structures becomes stiffening action due to the infills, earthquakes that have a richer frequency content at high frequencies have had a greater impact on the structure under study. Also, the average seismic fragility for the pre-damaged frame is less than the intact frame due to the damage caused by the main shock.

Aftershock capacity loss is assessed by diagrams in Figure 3 showing the different normalized capacity losses of bare and infilled frames in terms of average collapse PGA. Residual capacity loss is almost the same for bare and infilled frame up to an MS intensity of0.10 PGA. Beyond this point, the bare frame loss curve significantly diverges from the infilled one; achieving total residual capacity loss at 0.3054 g MS and 0.3082g PGA, respectively, for near and far field earthquake records (collapse in the mainshock). In correspondence to the same point, the bare and infilled frame

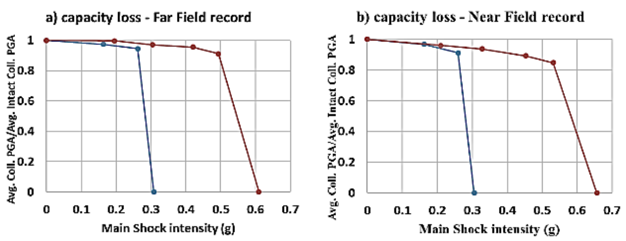

Fig. 3. Aftershock capacity loss diagrams: a) Far field earthquake; b) Near field earthquake

maintains 95% and 97% of the intact capacity, respectively. Therefore, the structure subjected to far field earthquake, about 2.2% more than near field earthquake, can maintain its capacity compared to the undamaged condition.

4- Conclusion

Based on the results of the analysis, it can be said that increasing the capacity of the intact bare frame against infilled frame under near field earthquake is about 17% higher than far field earthquake. According to the results of fragility curves subjected to far-field and near-field earthquake records, observed that collapse probability of 100% of the bare frame corresponded to 15% and 2.2% of collapse probability for the infilled frame, respectively, which indicates the effective role of masonry infilled in increasing lateral stiffness. The IDA curves of the bare and infilled frame show that the residual drift subjected to near field earthquake is about 30% higher than far field earthquake records.

Due to the limitation in the number of selected models in this paper, it is recommended to perform additional analysis with a larger number of models to complete the results of the present article. It should also be noted that due to the high volume of calculations, the effects of the vertical component of the earthquake have not been considered in the analysis.

References

[1] M. Dolšek, P. Fajfar, Simplified seismic assessment of infilled reinforced concrete frames, 2006.

[2] G. Mondal, S.K. Jain, Lateral stiffness of unreinforced brick infilled RC frame with central opening, Master of Technology Thesis, (2003).

[3] F. Di Trapani, M. Malavisi, G. Bertagnoli, L. Cavaleri, Evaluation of fragility of infilled frame structures subjected to aftershocks by means of double incremental dynamic analysis appraoch, in: 16th European Conference on Earthquake Engineering, Springer, 2018.

[4] F. Di Trapani, M. Malavisi, Seismic fragility assessment of infilled frames subject to mainshock/aftershock sequences using a double incremental dynamic analysis approach, Bulletin of Earthquake Engineering, 17(1) (2019) 211-235.

[5] S. Yaghmaei-Sabegh, R. Mahdipour-Moghanni, State-dependent fragility curves using real and artificial earthquake sequences, Asian Journal of Civil Engineering, 20(4) (2019) 619-625.

[6] N.Z.S.f.E. Engineering, Assessment and Improvement of the Structural Performance of Buildings in Earthquakes: Prioritisation, Initial Evaluation, Detailed Assessment, Improvement Measures: Recommendations of a NZSEE Study Group on Earthquake Risk Buildings, New Zealand Society for Earthquake Engineering, 2014.

[7] J.B. Mander, M.J. Priestley, R. Park, Theoretical stress-strain model for confined concrete, Journal of structural engineering, 114(8) (1988) 1804-1826.

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