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Seismic fragility analysis of prefabricated shear wall with dissipation devices under mainshock-aftershock sequences

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ABSTRACT

This study presents seismic fragility analysis of prefabricated shear wall with dissipation devices under earthquake main-shock-aftershock sequences. The model of prefabricated shear wall was established by using the finite element software ABAQUS. 80 seismic motions are chosen from PEER strong earthquake database and formed to the main-shock-aftershock sequences, which is according to the related laws. Based on the probabilistic seismic demand model, seismic fragility curves of the dissipation shear wall under the action of main shock and main-shock-aftershock sequences were established and studied. The fragility curves under the main-shock-aftershock sequences are above the fragility curve of main shock. It is concluded that the probability that structural damage value exceed a certain limit considering aftershock is larger than that of only considering the main shock, and the aftershock will further deepen the damage of the structure. Thus, the influence of main-shock-aftershock sequences should be taken into the seismic fragility analysis as well as the assessment of earthquake loss.

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1. INTRODUCTION

Earthquake is a kind of natural disaster with huge damage, which causes lots of casualties and property losses. Engineering structure will suffer from the aftershock after the main shock within a certain period according to many history earthquake data. In the process of a great earthquake, the structure will undergo different degrees of damage after main shock action, and the effect of aftershock will cause cumulative damage or even collapse. The research work on multiple earthquakes mainly focuses on the construction and combination method of the mainshock-aftershock sequences, the single-degree-of-freedom system and the structural response of the relatively simple frame structure system. Therefore, it is of great significance to compare and analyze seismic fragility of the high performance structure system under mainshock-aftershock sequences and the main shock. Shear wall structure is one of the widely used structural forms in many high-rise buildings at present. Shear wall with dissipation devices not only has good performance of anti-lateral but also has pretty performance of energy dissipation. Many scholars have made much research on structure system and mechanical performance of shear wall with energy dissipation devices, whereas, there are few studies on the seismic fragility analysis of the shear wall with energy dissipation devices under mainshock-aftershock sequences. To study on the seismic fragility of fabricated shear wall with dissipation devices under the action of mainshock-aftershock sequences, finite element models of shear wall with dissipation devices was established by using the finite element software ABAQUS.

2. DESCRIPTION OF MODEL

2.1 Prefabricated shear wall with dissipation devices

The finite element model is 16 storeys, 48m in height, the hole on the left side of the wall is 1m×1.5m, the hole in the right one is 1.5m×2m. Walls assembled by dampers, Figure 1 shown the position of damper on the shear wall. 80 seismic motions were chosen from PEER strong earthquake database, nonlinear dynamic time history analysis of the shear wall model was conducted under the mainshock-aftershock sequences and main shock. The seismic response data in terms of the maximum inter-storey drift ratio and top displacement are usually used as standard measure of nonlinear structural system response and can be related to specific damage stages.

2.2 Material model

Concrete element is analysed by the concrete damaged plastic model (CDP) in the finite element software ABAQUS. CDP is kind of continuous medium damage model which based on plasticity. Inelastic behavior of concrete is characterized by using isotropic damage elasticity combined with isotropic tensile and compressive plasticity, which assumed tensile cracking and compressed crushing as the main damaged mechanism. Yield surface evolution is controlled by hardening variables that are tensile equivalent plastic strain and compression equivalent plastic strain. In this paper bilinear kinematic hardening model (BKIN) is used, strengthen stage follows with the yield stage of the stress-strain curve.

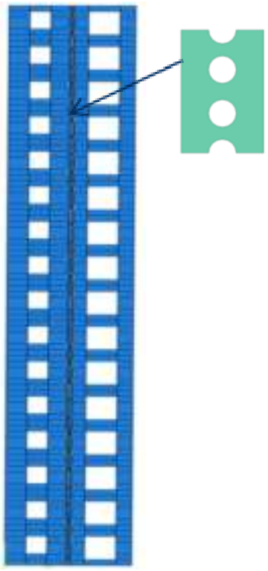

Fig. 1 Finite element model of shear wall

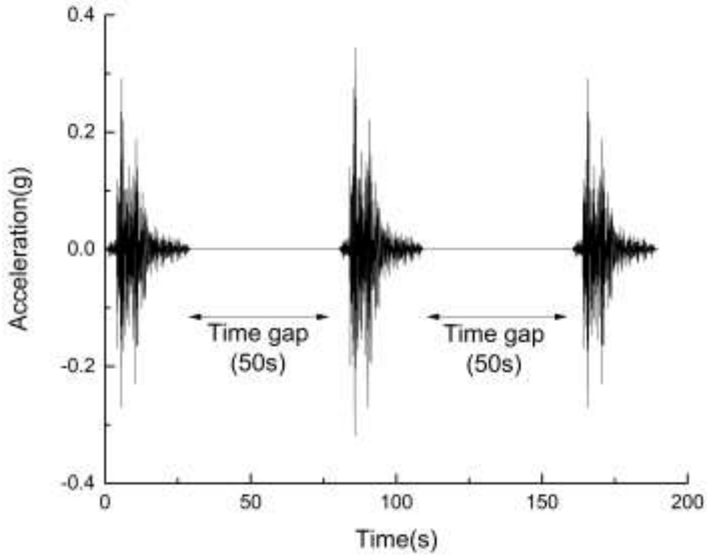

Fig.2 Time-history curves of acceleration of mainshock-aftershock sequences

2.3 Seismic input

According to the well-known Gutenberg-Richter law (Gutenberg B, Richter CF. 1954) and empirical relation between magnitude and PGA, which proposed by Joyner-Boore (1982), we know that for every seismic event with PGA equal to Ag,max, there will be two earthquakes with PGA equal to 0.8526·Ag,max. Main shock combined with two aftershocks as the seismic sequences that parameters are 0.8526, 1, 0.8526. Between two consecutive seismic events a time gap is applied, which is equal to 50s. This gap is absolutely enough to cease the moving of any structure due to damping. Time-history curves of acceleration of mainshock-aftershock sequences according to the above laws shown in Fig.2.

3. FRAGILITY ANALYSIS UNDER MAINSHOCK-AFTERSHOCK SEQUENCES

3.1 Probabilistic seismic demand

Probabilistic seismic demand model is aim to establish the probability relationship between the ground motion intensity and the structural seismic demand for a certain type of structure. Under the assumption that the structural seismic demand accords with lognormal distribution, Cornell (2002) suggests that the median of demand D and the intensity of ground motion IM following relation:

$$\ln \mu_D = \ln a + b \ln IM \quad (1)$$

$$\sigma_{D|M} = \sqrt{\frac{\sum_{i=1}^{N}\left[\ln(D_i)-\ln(aIM_i^b)\right]^2}{N-2}} \quad (2)$$

where *a* and *b* are unknown coefficients, D_i denotes peak value of seismic demand, IM_i denotes ground motion intensity. $\sigma_{D|IM}$ is the standard deviation of seismic demand.

The way to eatimate the three parameters, *a*, *b*, and $\sigma_{D|M}$ is to conduct a number of nonlinear analyses and then conduct a regression analysis of *lnD* on *ln IM*. This study considers the maximum inter-story drift ratio, as the seismic demand parameter for the development of fragility curves. Seismic demands under main shock (MS) and mainshock-aftershock (MS-AS) sequences are shown in Figure.3.

3.2 Seismic fragility analysis

Fragility of a structural system is defined as the probability that a system response exceeds a limit state when subjected to earthquake. Therefore, the fragility analysis can be calculated by substituting Eq.(1) and Eq.(2) into fragility equation, which is given by :

$$P(D \geq C|IM)=\Phi\left[\frac{\ln(IM)-(\ln(\mu_C)-\ln a)/b}{\sqrt{\sigma_{D|IM}^2+\sigma_C^2}/b}\right] \tag{3}$$

where μ_D and μ_C are the median of seismic demand and structure capacity respectively, σ_C is the standard deviation of structure capacity.

In order to generate structural fragility curve, the limit state of a structure must be defined. Four limit states representing slight structural damage (LS-1), moderate structural damage (LS-2), severe structural damage (LS-3), and collapse (LS-4) are established to characterize the degree of damage incurred in building during earthquakes. Seismic fragility curves shown as followed in Fig.4.

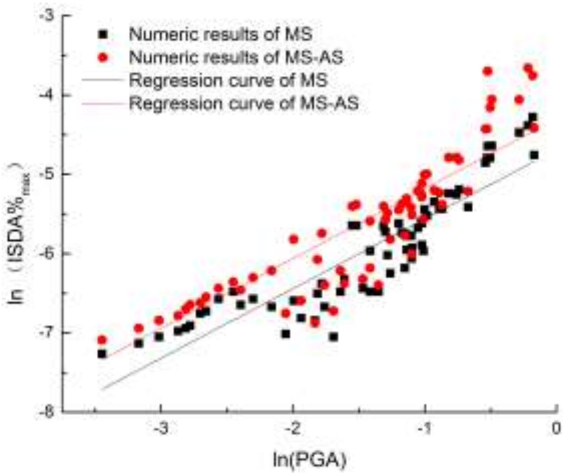

Fig.3 Seismic demand analysis

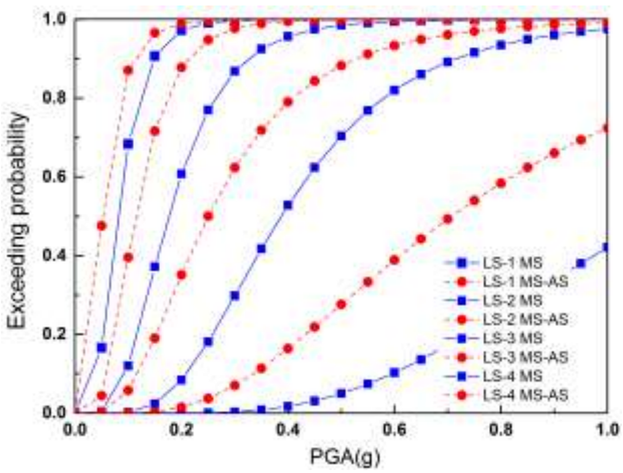

Fig.4 Fragility curves

4. CONCLUSIONS

From the fragility curves we can learn that, the failure probability of the prefabricated shear wall with dissipation devices under the mainshock-aftershock sequences at the same performance level is greater than that of the main shock under the same earthquake intensity. Since the influence of main-shock-aftershock sequences should be taken into the seismic fragility analysis as well as structure design.

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