論文題目　「Structural Seismic Resilience Assessment Based on Shifted Lognormal Distribution」
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[Abstract]

Seismic resilience assessment, which aims at quantitatively evaluate the structural capability to maintain a level of functionality due to an earthquake event and recovery to the expected state as soon as possible had gradually received wide acceptance over the past decades. A conceptualization framework to measure seismic resilience is firstly presented in 2003. Resilience of systems is defined as consisting of four properties: robusness, redundancy, resourcefulness and rapidity. A unified teirminology defined as seismic resilience index is proposed in 2010 to make the quantification on seismic resilience possible. In this methodology, seismic resilience is regarded as an extended concept of performance-based seismic design under the consideration on time dimension. Due to which, resilience index is evaluated through two parts, i.e., loss due to earthquakes and recovery process after the events. This framework was subsequently widely discussed and applied in the following correlated studies. Research on seismic resilience has made rapid progress in the past decades over the world. In Japan, although the correlated research increased following the establishment of the High Resilience Structural System Subcommittee in 2007, most of the studies still remain on the theoretical and application stage. Efficient and rational methodology for quantificating seismic resilience of single structures is especially important for obtaining the basis for judgement in decision making for disaster mitigation. The

contribution from structural engineering is aimed at accurately evaluating the structural failure probability due to earthquakes (i.e., the loss evaluation for seismic resilience assessment). Because of the limited information and complicated structural analysis, current method is achieved by employing two probabilistic models, i.e., two-parameter lognormal structural demand model in structural fragility analysis and Frechet distribution for annual maximum peak ground motion in probabilistic seismic hazard analysis. These two models are widely applied in practical application, however, the accuracy and appropriateness of them have received little attention. The main object of this research is to modify the current methodology of seismic resilience assessment on structures by application of two proposed probabilistic models that could be used in structural fragility analysis and probabilistic seismic hazard analysis to improve the accuracy and validity of the analytical results.

This dissertation consists of five chapters and the contents of each chapter are summarized as follows:

In chapter 1, the background, objective and organization of this study are described.

In chapter 2, A new structural demand model based on shifted lognormal distribution was proposed for analytical seismic fragility analysis. The model's performance was verified based on a large amount of analytical engineering demand parameter data obtained from the nonlinear dynamic analysis. From the goodness-of-fit tests based on the large amount of analytical engineering demand parameter (*EDP*) data, the proposed model showed a better fitting effect than the existing 2P-lognormal model and thus, proved to be a more appropriate assumption in seismic fragility analysis. The relationships between the first three central moments of *EDP* and earthquake intensity could be estimated to generate continuous fragility curves efficiently. Specifically, the mean and standard deviation of the *EDP* could be estimated through linear regression at an arbitrary earthquake intensity level, and the skewness of the *EDP* could be estimated as a fixed value. The analytical fragility curves generated using the proposed and existing models were compared with the Monte-Carlo Simulation results in a numerical example of a simplified steel frame structure. From the comparison results it was observed that the proposed structural demand model showed different degrees of accuracy improvement compared to the existing 2P-lognormal model for different performance limit states and earthquake intensity levels. Thus, the proposed model proved to be more appropriate for use as a structural demand model in a seismic fragility analysis. In another numerical seismic fragility analysis example on an RC shear wall frame structure, the relationships between the first three central moments of the structural demand and earthquake intensity demonstrated the necessity of consideration the skewness, as well as the effectiveness of the proposed model in the case of different selections on earthquake intensity measure.

In chapter 3, a probabilistic model for annual maximum peak ground motion is proposed based on shifted lognormal distribution. From the comparisons of probability density function and cumulative distribution function of the two probabilistic models fitting the histogram of 102-year annual maximum peak ground acceleration and the goodness-of-fit tests, although the Fréchet model has already performed quite well, the proposed model still shows a better global fitting effect. And from the comparisons of seismic hazard curves generated by the two models fitting to the exact seismic hazard data, the proposed model shows more accurate prediction results especially for low annual exceedance probability levels, while the results from the Fréchet model shows unphysical overestimation on expected values, which is quite important when long return period in seismic design should be considered. For estimation on common-used statistics, i.e., mean and standard deviation, Fréchet model gives a considerably overestimation on standard deviation due to the existence of Gamma function. Limitation on central moments calculation of Fréchet distribution is quite unfavorable for its application as a probabilistic model in reliability-based design. The proposed probabilistic model was applied in two numerical examples. Compared with Fréchet model, the proposed model shows relatively accurate performance in generating continuous seismic hazard curves by fitting the limited analytical seismic hazard data. And its robustness for different types of seismic hazard data (exceedance probability in arbitrary years) and different types of earthquake intensity measures is also proved.

In chapter 4, a modified methodology with the application of the proposed structural demand model and annual maximum peak ground motion model for conducting seismic resilience assessment on structures is summarized. In a numerical example, seismic resilience assessment on two fictitious steel frame models with and without braces is conducted by the proposed methodology with an assumption of exponential recovery process. As the results, total failure probability estimated by the existing method tends to be overestimated in mild performance limit states and underestimated in severe performance limit states, which is uneconomical even unsafe for decision making in structural seismic design. Compared to which, the proposed method is proved to be validity and rational in seismic resilience assessment.

In chapter 5, conclusions of this study are summarized.