SIMPLIFIED METHOD FOR CHARACTERISTIC FRAGILITY CURVES EVALUATION

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1. INTRODUCTION

For improving the probabilistic failure risk assessment of typical RC pier structures including the uncertainty of information on actual material parameters, numerical analysis is being conducted by modeling the statistical distribution of the structural material and soil parameters. Variable seismic risk is encounter over the path of the road network based on each pier location. The failure of any pier could severe the communication network until restoration work is being completed; therefore a detailed probabilistic failure risk assessment is being conducted.

Monte Carlo Simulation (MCS) is the method of choice for the identification of the probabilistic failure behavior of the RC structures. MCS method requires generation of a large number of analysis cases for properly covering the distribution of the structural parameters and the uncertainty of the loading.

The Simplified Fragility Evaluation method was shown to provide a faster method for determination of fragility curves, by using the probabilistic distribution of the structural response at a single loading level and with the corresponding loading value inducing structural failure identified as part of the method, see Minesawa et.al (2016). The speed gains are related of the overall reduction of the number of analysis cases required for determination of characteristic fragility. The computation efficiency makes method suitable for the evaluation of the probabilistic risk of failure of typical RC piers.

2. SIMPLIFIED FRAGILITY EVALUATION METHOD

The Simplified Fragility Evaluation Method has been proposed by Minesawa et.al (2016) for speedy fragility evaluation of RC piers. Simplified Fragility Evaluation Method consists of following analysis steps shown schematically in Fig.1:

At first, the characteristic response curve of the analyzed structure is determined with the characteristic values of the input parameters by nonlinear analysis at incremental levels of the input earthquake loading. The loading point corresponding to intersection point of the characteristic response curve with safety threshold level is determined and the analysis of the lumped mass structural analysis model is conducted with the MCS modeled statistical distribution of significant input parameters variability. The Simplified Fragility Evaluation Method is determining for each parameter combination the safety threshold exceedance level, using the mean reference characteristic curve as reference for the structural behavior. The cumulated failure probability is summarized into the characteristic fragility curves. The characteristic fragility curves determined by Simplified Fragility Evaluation Method with one complete set of MC statistical parameters are comparable with the equivalent fragility curves determined by full implementation of the MC method. The computational speed gain of the Simplified Fragility Method versus the MC method is significant and largely proportional to the number of the FE analysis cases, allowing for speedier analysis of RC pier structures.

The Simplified Fragility Evaluation Method is being applied for determination of the failure probability of typical RC pier structure for determination of the characteristic fragility curves and for determination of the failure probability.

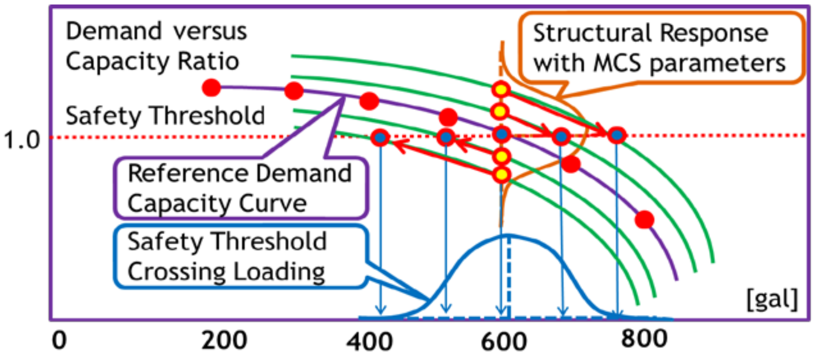

Fig.1 Simplified Fragility Evaluation Method flow

Table.1 Constitutive material characteristics of the RC pier

Structural Material	Material Parameter	Mean Value μ	Standard Deviation σ
Concrete 24.0 [N/mm2]	fc [N/mm2]	32.0	1.215
	ft [N/mm2]	$ft = 0.23 * f'c^{2/3}$ (1)	
	Ec [KN/mm2]	$Ec = 8.39*f'c^{1/3}$ (2)	
Soil N50	Vs[m/s]	300	31.06

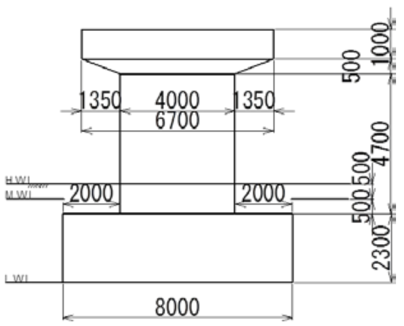

Fig.2 RC pier dimensional characteristics

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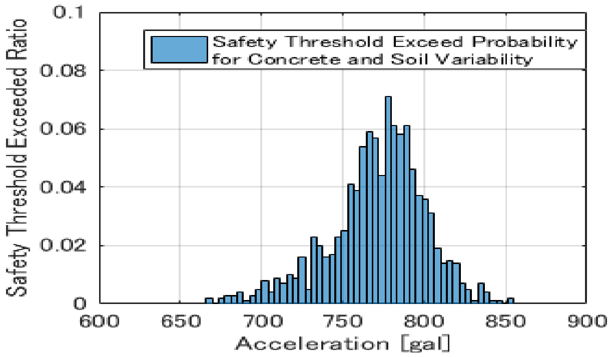

Fig.3 Safety threshold exceed probability by Simplified Fragility Evaluation Method

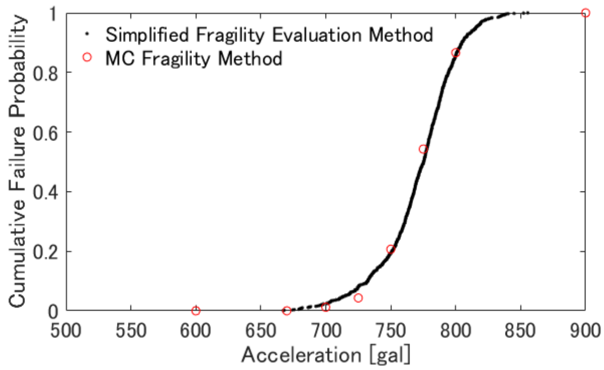

Fig.4 Seismic fragility curves by MC and Simplified Fragility Evaluation Methods

Table 2 Seismic annual failure probability

Region	Pf Simplified Method	Pf MC Method	Pf MC vs Pf Simplified Eval. Meth. [%]
S	1.326E-02	1.313E-02	99.023
K	2.026E-04	2.012E-04	99.304
M	5.775E-03	5.680E-03	98.352

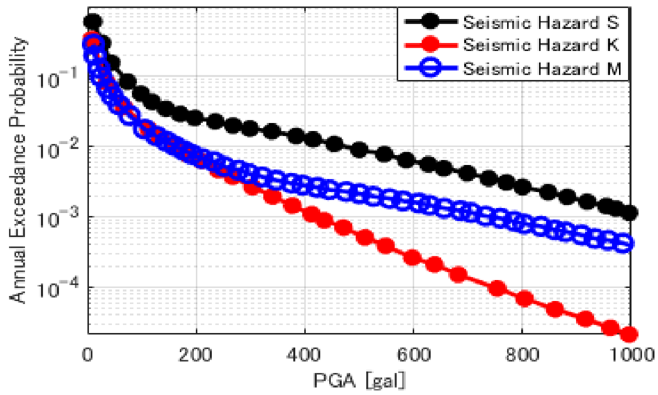

Fig.5 Seismic hazard curves for the three seismic regions

3. SIMPLIFIED FRAGILITY EVALUATION METHOD FOR RC PIER PROBABILITY OF FAILURE

A typical RC pier described in JSCE(2002) with dimensional characteristics shown in Fig. 2 was modeled by numerical analysis of the soil and concrete material variability with the parameters described in Table.1. MCS is used to generate the soil shear velocity and concrete compressive strength distribution of parameters, while other variables are determined as per Eq. (1) and (2). The data analysis system automatically generates the necessary analysis model input parameter variability and post-processes the results for generation of the fragility curves. Failure criterion is the displacement limit exceeded due to the bending with axial force, considering the horizontal translation term, the safety threshold exceedance probability is being shown in Fig. 3. The Simplified Fragility Evaluation Method computed median characteristic fragility curves are summarized in Fig. 4 vs. MC Method and are used for failure probability assessment. The seismic annual failure probability P_f is computed as per Equation (3) using the cumulative failure probability represented by the mean fragility curves datasets $F_s(s)$ as plotted in Fig. 4 and the mean seismic hazard curves G(s) determined by Annaka et al. (1998) for three seismic regions in Japan (named S, K and M) shown in Fig. 5. The seismic annual failure probability P_f as determined by Simplified Fragility Evaluation and MC Methods are reported in Table 2.

$$P_f = \int_{s=0}^{+\infty} -F_S(s)\,\frac{dG(s)}{ds}\,ds \qquad (3)$$

4. CONCLUSIONS

The described fragility evaluation method could determine the characteristic fragility curves in a simplified manner, considering in structural analysis the probabilistic uncertainty of multiple parameters. Simplified Fragility Evaluation Method could provide a faster way to determine the earthquake level where response exceeds certain safety threshold, helping reduce number of FEM cases required for fragility evaluation. Application of the suggested method to the probability of failure analysis was shown for a typical RC structure.

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