EVALUATION OF SEISMIC FRAGILITY ANALYSES

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ABSTRACT :

In last decades, through further development of computer technology in civil engineering, so many different seismic analyses became possible and accuracy of the analysis is increased. Therefore there are lots of methodologies for seismic assessment in use. Including the probabilistic approaches into the seismic assessment offer more realistic approaches. Recently, seismic assessments are done with this consideration. Fragility analysis is one of them. The fragility analysis which is a system reliability analysis with correlated demands and capacity is performed with different methodologies to establish the probabilistic characterization of the demands in different aspects. In the present study, probabilistic seismic analyses to define the structural seismic behavior are evaluated. A representative R/C frame structure is taken in to consideration in the analytical part. A comparison is realized with the results of different methodologies as Monte Carlo Simulations and analytical based analysis.

KEYWORDS: Probabilistic seismic assessment, evaluation of the methodologies, fragility analysis, Monte Carlo simulations

1. INTRODUCTION

Through advances in computer analysis techniques as the computer technology, nonlinear structural analysis becomes possible (Irtem et al., 2007). Moreover, probabilistic analysis could be added in to the seismic assessments, which makes the analyses more accurate and more dependable. In structural behavior assessment analysis, with the technological developments in computing in civil engineering, the deterministic assessment methods are thought to be insufficient to define structural behavior under earthquake effect. Due to the uncertainty and random variables in the analysis it is necessary to include probabilistic assessment into the analysis. Including the probabilistic approaches into the analyses for definition of seismic structural behavior will give more rational results. A probabilistic methodology is realized for using to make a rehabilitation decision according to seismic hazard and system performance (FEMA 273, 274, 356, 1997; FEMA 440, 2005).

The main objective of this paper is to evaluate the methodologies for probabilistic seismic assessment in terms of fragility assessment. The probabilistic seismic performance is measured by fragility curves, that is, the probability of system failure as a function of earthquake consequences of system damage and failure, and system probability of failure. In the present study, probabilistic seismic analyses with fragility analysis to define the structural seismic behavior are evaluated. A representative R/C frame structure is taken in to consideration in the analytical part. A comparison is realized with the results of different methodologies. These methodologies are as by Monte Carlo simulations and analytical based analyses.

2. FRAGILITY ANALYSIS

Fragility analysis is the analysis for seismic loss estimation in built environments. They represent the probability of exceeding a damage limit state for a given structure type subjected to a seismic excitation (Shinozuka et al., 2000, Ellingwood et al., 1980). In the literature there are various type of fragility analysis available. The damage limit states in fragilities may be defined as global drift ratio (maximum roof drift normalized by the building height), inter story drift ratio (maximum lateral displacement between two consecutive stories normalized by the story height) or story shear force etc. Fragility curves involve uncertainties associated with structural capacity, damage limit state definition and records of ground motion accelerations (Hui, 1991; Hwang and Huo, 1994; Hwang and Jaw, 1989; Corvers, 2000).

Considering a dynamic system subjected to a natural hazard event as an earthquake resulting in a multi-dimensional forcing function F(t), $t \geq 0$, acting on the system. Denoting by F^1 (t), $0 \leq t \leq \tau$, a relevant multi-dimensional system response process, where τ is a timing. Figure 1 illustrates the relationship between the data F(t) and out $F^1(t)$.

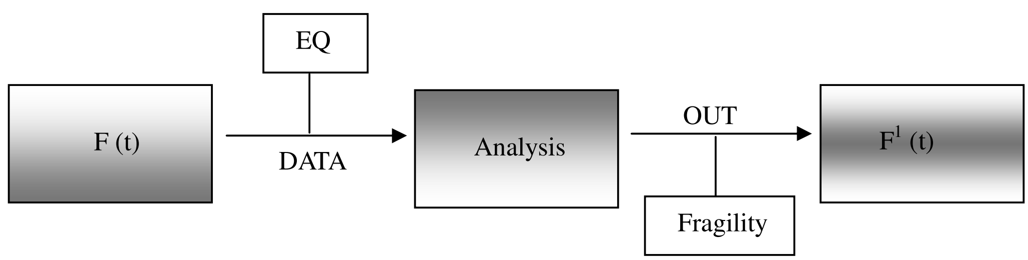

Figure 1 Input-output relationship for Fragility Analysis

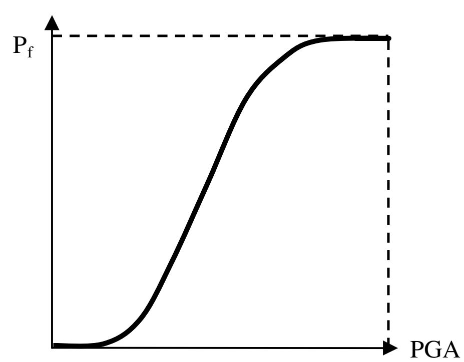

Figure 2 Schematical of Seismic Fragility Curve

3. FRAGILITY BY MONTE CARLO SIMULATIONS

Monte Carlo Methods are generally used to define some method which demonstrate utilities a sequence of random variables. By using Monte Carlo methodologies, very close results of the study could be achieved. The methods can be applied on engineering probabilistic problems easily. Monte Carlo methods can be used to simulate random variables since these processes can be described by probability density functions. Monte Carlo methods may also be used to solve deterministic problems with no stochastic content, if the problem could be translated into density function. Once the probability density function is known, Monte Carlo simulations can be performed by random sampling. After many simulations, the solution of the problem is obtained by evaluation of the simulation results.

Monte Carlo simulation tools become very popular in engineering fields. Since many simulations are usually necessary to obtain results with satisfactory precision, the generation of random numbers, the simulation itself and the evaluation of the results are commonly performed on a computer. The rapid increase of the capacity and speed of computers in last decades has enabled the execution of simulation with a large numbers of random variables and simulations. With the increase of computer ability, many problems that were practically unsolvable due to practical limitations became solvable. Monte Carlo simulation methods are both useful for research and application. Probabilistic assessments managed by Monte Carlo simulations based on a simple methodology as given below.

$$P_{f,me}(D,\phi) = \frac{\iota\{z_i(t) in D(0,\tau)\}}{n_s} \tag{3.1}$$

where τ is generally taken as the duration of $f_i(t)$.

4. FRAGILITY BY ANALYTICAL APPROXIMATION

Fragility is the probability that a response of both structural and nonstructural systems exceed a critical level if subjected to seismic loading of specified intensities. The seismic ground motions are based on the parameters defining its probability law as given with d=2 components, Φ_1 = the earthquake moment magnitude m, and Φ_2 = the distance r from the seismic source to the site. The seismic ground acceleration at system site, generated by a seismic event with moment magnitude m and source-to-site distance r, is modeled as;

$$X(t) = e(t)\,Y(t),\ 0 \leqslant t \leqslant \tau \tag{4.1}$$

where τ is the total duration of the seismic event, e(t) is a deterministic modulation function, Y (t) is a Gaussian and non-Gaussian process with probability law.

Fragility levels are assumed as in lognormal distribution. For determination of parameters of mean and deviation of lognormal distribution, smallest square root method is applied. In Eq.4.2, fragility level is defined for each damage level and in different earthquake values.

$$F_{ij} = \Phi\left(\frac{\ln(DR_i) - \mu_{\ln(DR)}}{\sigma_{\ln(DR)}}\right) \tag{4.2}$$

Where, Φ is standard normal distribution function, μ and σ are mean and lognormal standard deviation values of damage parameters respectively.

5. COMPARISON THE METHODOLOGIES ON AN EXAMPLE BUILDING

Here, to apply the performance based methods, an analytical example is given. A particular structure type is considered in this study, namely 4-story ordinary R/C existing reinforced concrete frame structure, which generally do not comply with modern seismic resistant design and construction practice. The building constitutes the majority of the vulnerable building stock in countries, which prone to earthquakes. Also it is a fact that fast urban growth after 80s, substantiating uncontrolled development of the physical environment, is the primary source of such existing risks.

The structure used in the analyses is 4-story R/C building with 3m story height, 6m span. The story weight is 10000kN. It is at the 1st zone and Class D soil type. The selected structure is dimensioned by SAP2000 (Wilson and Habibullah, 1998). In figure 3, selected structure is given.

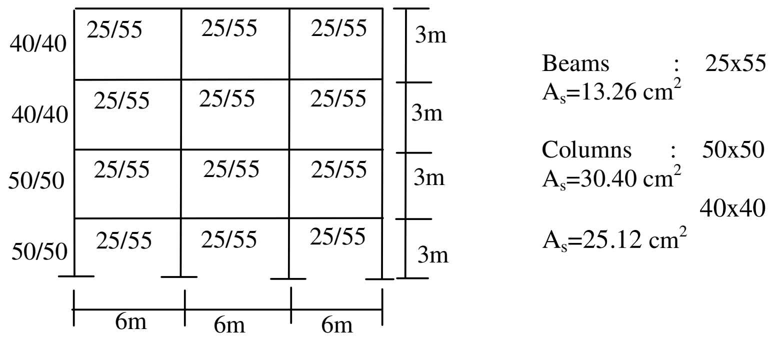

Figure 3 Sample 4-story structure

Table 1. Selected Earthquake Data

No	Data	Date	Code	PGA (g)	Soil Type
1	Parkfield	28/06/1966	C12320	0.0633	B
2	Morgan Hill	24/04/1984	GIL067	0.1144	B
3	Kocaeli	17/08/1999	ARC000	0.2188	B
4	Morgan Hill	24/04/1984	G06090	0.2920	B
5	Coyota Lake	06/08/1979	G06230	0.4339	B
6	Northridge	17/01/1994	ORR090	0.5683	B
7	Loma Prieta	18/10/1989	CLS000	0.6437	B
8	Kobe	16/01/1995	KJM000	0.8213	B
9	Santa Barbara	13/08/1978	SBA222	0.203	B
10	Livermore	27/01/1980	LMO355	0.252	B

By considering selected building, fragility analyses were realized by Monte Carlo simulation and analytical way. Consideration of these two methodologies is very important in the manner of probabilistic seismic assessment. Probabilistic approaches are based on fragility analysis. Fragility analysis is generally realized by analytically. Recently, by computer technology, more complex analysis can be managed. Therefore, using Monte Carlo simulations for fragility analysis become possible. Here, fragility analysis was realized by Monte Carlo simulations and analytically. The results were compared with each other. For the analysis, ten different earthquake data are selected. The data are listed in Table 1.

In figure 4, fragility curves are sketched by Monte Carlo simulations and analytical way. As seen in the figure, curves are very close to each other. But Monte Carlo simulation results give higher probability of failure values comparing to the analytical way.

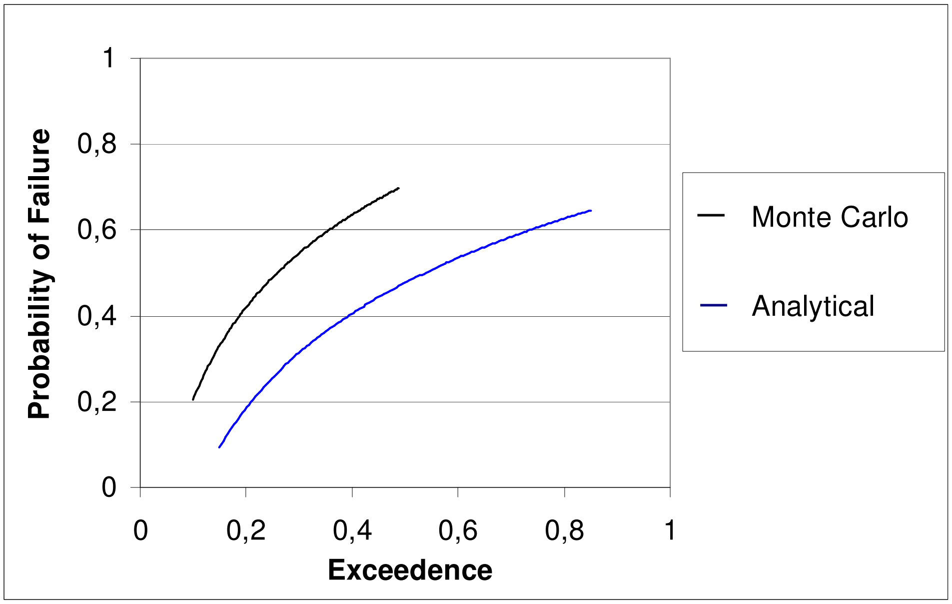

Figure 4 Fragility Curves of Sample Buildings

6. CONCLUSIONS

In this study, new and conventional fragility methodologies are evaluated. New methodology is namely Monte Carlo simulations and conventional methodology is namely analytical approximations. After definition of the methodologies, an application is realized with a selected sample R/C structure.

In comparison of these methods, the methods give close results with each other in the analysis of symmetric structures as the selected one. Simulation based fragility analysis is counted more reliable. For Monte Carlo Simulation based and analytical seismic assessment, acceleration values of selected earthquakes were used in the analyses. For further research, number of earthquake data and sample buildings should be increased.

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