Amirkabir Journal of Civil Engineering

Amirkabir J. Civil Eng., 52(3) (2020) 193-196
DOI: 10.22060/ceej.2018.14827.5767

Probabilistic Seismic Hazard Analysis for Tehran and Suburbs by Using of First Order Second Moment Algorithm

M. Shamekhi Amiri, Kh. Mansouri Seresht*
Department of Civil Engineering, Shahrood University of Technology, Shahrood, Iran

ABSTRACT: One of the most damaging natural disasters is an earthquake which random process of its motions has made predicting and preventing its occurrence impossible, but it is possible to reduce the probable damages caused by earthquakes through probabilistic seismic hazard studies. Iran is one the countries that always has been exposed to the damages of this natural phenomenon. The experiments of many countries that are at high risk of earthquakes, has shown that damages can be reduced when seismic hazard analysis is achieved in structural design process. Seismic hazard analysis requires the earthquake data and obviously more accurate data can lead to results with more precision. The magnitude, location and focal depth of the earthquakes are the most basic data that needs to be updated carefully. These parameters have a major role in the estimation of the probabilistic seismic hazard analysis in the different regions. The city of Tehran which is the capital and the most populous city of Iran was chosen as our study area. The current research includes a history of more than 300 earthquakes in the past 117 years, which has been analyzed for Tehran and its suburbs with the aim of conducting a new FOSM (First Order Second Moment) algorithm. In this method, four ground motion relationships with the same weight were also used. Based on given design seismic levels and the Iranian Standard No.2800, the present study had the PGA in two levels. The first level which is, Design Basis Earthquake (DBE) defines the peak horizontal accelerations with 10% probability of exceedance in 50 years that was expected to occur once in approximately 475 years. The second is Maximum Considered Earthquake (MCE) that defines the peak horizontal accelerations with 2% probability of exceedance in 50 years which was expected to occur once in approximately 2,475 years. According to the FOSM algorithm, the estimated PGA for both levels was 0.30061 g and 0.55666 g, respectively.

Review History:

Received: 8/21/2018
Revised: 10/19/2018
Accepted: 10/31/2018
Available Online: 12/15/2018

Keywords:

FOSM algorithms
Probability seismic hazard
Annual rate for earthquake
Design base
Return Period

1. INTRODUCTION

Earthquakes, as one of the most devastating and unpredictable natural hazards, have caused numerous loss of life and have had a significant economic impact in recent human history. The global seismic risks are amplified due to population increase, urbanization, and industrial development. While there is no way to prevent an earthquake, there are ways to locate, control and improve constructions and investments to minimize the disastrous effects [1]. Seismic hazard analyses involve the quantitative estimation of ground –shaking hazards at a particular site. Seismic hazards may be analyzing deterministically, as when a particular earthquake scenario is assumed, or probabilistically, in which uncertainties in earthquake size, location and time of occurrence are explicitly considered. Although seismic hazard analysis is a critical part of the development of design ground motions [2]. As a result, the key scope of this study was performing a new seismic hazard assessment for this high-seismicity region, using the FOSM[1] algorithm to estimate the annual rate of the earthquake motions with the statistics of the earthquakes in the past 117 years that directly generates the uncertainty of the parameters in the results and highly effective in analyzing uncertainty. This method relies on the output variables by using the linearization of the functions of the variables and input parameters to the output variables.

2. PROBABILISTIC SEISMIC HAZARD ANALYSIS

PSHA[2] considers all possible magnitude earthquakes (usually above some minimum magnitude, on all significant sources, at all possible distances from the site, with consideration given to the likelihood of each combination. Therefore, using PSHA allows a potential facility to be designed for ground motion with a specified probability of exceedance. Obviously, the realism of a seismic hazard analysis is dependent on many factors, including the assumption that the sources chosen are realistic and reasonably complete (a difficult feat in itself in that one is estimating future seismic activity not only with regard to magnitude but also location) [3].

1 First Order Second Moment

*Corresponding author's email: mansouri.khalil7@gmail.com

2 Probabilistic Seismic Hazard Analysis

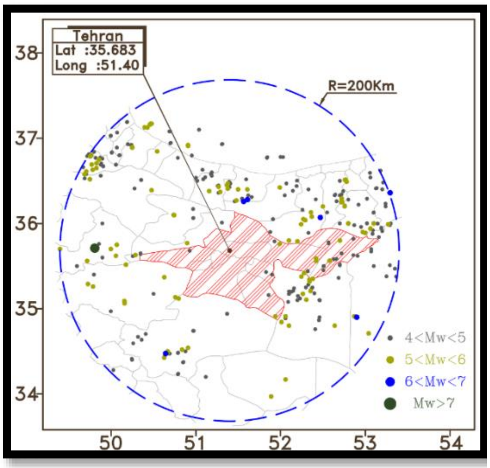

Fig. 1. The locations of 366 earthquakes from Tehran from 1900 until 2017

3. THE FOSM ALGORITHM

This method is based on the Taylor series expansion of the performance function about the expected values of the random variables. If only the first-order terms of the expansion are retained, the expected value of the performance function for independent random variables may be approximated by [4]:

$$E(Y) = f\{E(X_1).E(X_2), \ldots, E(X_n)\} \quad (1)$$

Understandably, $E(X_i)$ is the mean value of X_i, the input data of probabilistic analysis. On the other hand, based on the FOSM algorithm, the variance of Y (denoted as $V(Y)$) can be approximated as follows [5]:

$$V(Y) = \sum_{i=1}^{n}\{\frac{\partial Y}{\partial X_i}V[X_i]\} + 2\sum_{i=1}^{n}\sum_{i=j}^{n}\{\frac{\partial Y}{\partial X_i}\frac{\partial Y}{\partial Xj}Cov[X_i X_j]\} \ ; \quad \text{for } i < j \quad (2)$$

where n denotes the number of X_i *s*, and *Cov* is the covariance between two variables. For the case that any of two input variables are independent of each other (covariance is zero when two variables are independent), the variance of Y can be approximated as follows [6]:

$$V(Y) = \sum_{i=1}^{n}\{\frac{\partial Y}{\partial X_i}V[X_i]\} \quad (3)$$

In summary, Eqs. (1)–(3) present the key algorithms of the FOSM probabilistic analysis, which is derived from the Taylor expansion on the performance function $Y = f(X_i s)$ [5].

4. GROUND MOTION MODELS

As with any seismic hazard analysis, ground motion models are the performance function of such an analysis. Generally speaking, ground motion models are an empirical relationship characterizing the correlation between earthquake ground motion and earthquake magnitude and source-to-site distance combined. In this method, four ground motion relationships with the same weight were also used. Amiri Ground motion model (2014), Zare Ground motion model (1999), Campbell & Bozorgnia Ground motion model (1994), Akkar & Bommer Ground motion model (2014) are the four ground motions that used.

Table 1. Summary of the FOSM analyses for earthquake hazard analysis

Ground Motion Models	Variance	Standard Deviation
Amiri	0.138	0.371
Zare	0.145	0.380
Campbell & Bozorgnia	0.618	0.786
Akkar & Bommer	0.108	0.328

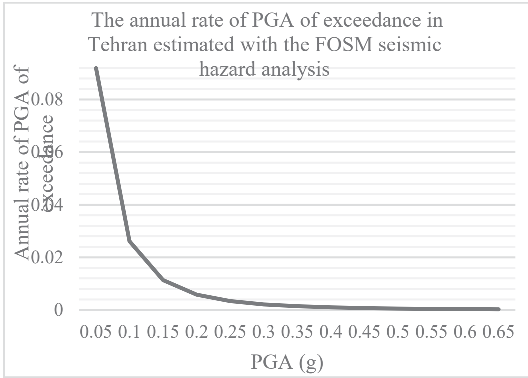

Fig. 2. Hazard Curve for Tehran estimated with FOSM algorithm

5. FOSM SEISMIC HAZARD ANALYSIS

From the earthquake catalog, Figure 1 shows the spatial distribution of 366 earthquakes (Mw>4 and D<200 km) around the center of Tehran.

With such input data and the ground motion models given, the FOSM algorithm in Eqs. (1)– (3) was used in order to calculate the mean and variance PGA induced by such earthquakes, as well as its standard deviation. The output analysis is shown in Table 1.

6. HAZARD CURVE FOR TEHRAN ESTIMATED WITH THE FOSM ALGORITHM

With the input data, the governing Table 1, and using the standard deviation of the PGA for the probabilistic seismic hazard assessment, and calculated four hazard curves for each ground motion relationship and combination with same weight and drawn a unit hazard curve for Tehran in Figure 2.

7. RESULTS AND DISCUSSION

It has been pointed out that not a seismic hazard assessment is perfect without challenge so that the robustness of a seismic hazard analysis is not related to methodology, but to a transparent and repeatable process. Therefore, like many others, this FOSM seismic hazard assessment, which is repeatable with the same input data, is a new, scientific reference to the levels of seismic hazard in Tehran [5].

8. CONCLUSIONS

The result showed that the annual rate for the earthquake with induced PGA exceeds based on given design seismic levels and the Iranian Standard No.2800, The first level which is, Design Basis Earthquake (DBE) defines the peak horizontal accelerations with 10% probability of exceedance in 50 years that is expected to occur once in approximately 475 years. The second is the Maximum Considered Earthquake (MCE) that defines the peak horizontal accelerations with 2% probability of exceedance in 50 years which is expected to occur once in approximately 2,475 years. According to the FOSM algorithm the estimated PGA for both levels was 0.30061 g and 0.55666 g, respectively.

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HOW TO CITE THIS ARTICLE

M. Shamekhi Amiri, Kh. Mansouri Seresht, Probabilistic Seismic Hazard Analysis for Tehran and Suburbs by Using of First Order Second Moment Algorithm, Amirkabir J. Civil Eng., 52(3) (2020) 193-196.

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