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Convex set theory-based seismic hazard analysis of low seismicity area

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ABSTRACT

Historical seismic data and seismogenic information are quite scarce for the low seismicity region, and modeling the parameters uncertainties based on probabilistic model is suspicious. The convex set theory-based seismic hazard analysis approach is proposed. The uncertainties of b value, the annual occurrence rate ν and the upper bound magnitude M_u are described by the envelop bound convex model and the ellipsoidal bound convex model. Convex analysis method and China probabilistic seismic hazard analysis methodology are combined to perform a bound seismic hazard analysis for Ningbo city, China. The seismic intensity interval obtained using the bound seismic hazard analysis is compared with that calculated using China probabilistic seismic hazard analysis methodology. The sensitivity analysis indicates that the interval of seismic intensity is most sensitive to the annual occurrence rate ν. Furthermore, the different convex models have little effect on the interval of seismic intensity.

1. Introduction

Probabilistic seismic hazard analysis (PSHA) aims to estimate the likelihood that selected ground motion parameters will be exceeded, at a site, within a reference time interval. Uncertainty of geological and seismologic information leads to strong uncertainties in each module of seismic hazard analysis, such as the source zones, the seismicity parameters and the attenuation relationship. The uncertainty in models and parameters of PSHA was firstly investigated for seismic hazard assessment of nuclear power plants in middle and eastern United States by McGuire [1], and the aleatory and epistemic uncertainties are modeled by logic tree methodology. The normal distribution function was employed to model the uncertainty of the source zone by Bender [2], and the uncertainty effects in source zone on assessing the seismic hazard were discussed. The use of logic trees for ground-motion prediction equations in seismic hazard analysis was presented by Bommer et al. [3]. The logic trees method was also employed to investigate the uncertain effect of source model, recurrence rate, attenuation relation and site on assessing the seismic hazard [4]. The influence of different procedures for calculating seismic hazard, epicentral parameters, source zone models, frequency-magnitude parameters, maximum earthquake magnitude values and attenuation relationships were considered for sensitivity analysis of seismic hazard of western Liguria [5]. The seismic hazard of Sweden, Finland and Denmark was estimated by Wahlström and Grünthal [6] using different logic tree methods. Various available models of seismicity and ground-motion attenuation were used as the alternative variants in logic tree method to assess the seismic hazard of Romania [7]. Sensitivity of PSHA results to ground motion prediction relations and logic tree weights were explored by Sabetta et al. [8]. The epistemic uncertainty can be modeled flexibly in the Monte Carlo simulations-based seismic hazard analysis method, and it is also applicable for seismic hazard analysis in a low to moderate seismicity area [9–11]. Hu and Chen [12] assumed that all the uncertainty including randomness, fuzziness and ignorance in seismic hazard assessment came from incomplete knowledge, and a unified probabilistic treatment may be applied to any combination of all three types of uncertainty.

Mualchin [13] remarked that current understanding of earthquake processes and limited data do not warrant overly complex analyses using logic tree methodology. Such analysis tends to divert attention away from hazard concerns and the investigation costs more in both time and money without necessarily improving seismic safety of structures. The use and misuse of logic trees in probabilistic seismic hazard analysis were also analyzed by Bommer and Scherbaum [14]. The results derived by Grandori et al. and Klügel shows that the PSHA based on multiple expert opinions was intrinsically unreliable when the dispersion was very significant, i.e., the mean value may not coincide with the true value in these situations [15,16].

The seismicity parameters, such as b value, the annual occurrence rate ν and the upper bound magnitude M_u, are found to be all highly uncertain and have strong effects on seismic hazard assessment. The uncertainties of theses seismicity parameters are modeled by the probabilistic model when the parameter is consistent with a certain distribution in the current process of PSHA. Besides, the logic tree methodology, which combined all possible alternatives, is the most popular way for dealing with the parameter uncertainty. However, no consensus is obtained on

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