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Probabilistic assessment of earthquake insurance rates for important structures: Application to Gumusova–Gerede motorway

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Abstract

A probabilistic model is presented for the assessment of the earthquake insurance rates for important engineering structures, for which the seismic losses could be quite significant. The proposed model is used to estimate the earthquake insurance premiums for the structures taking place in the Bolu Mountain Crossing in the Gumusova–Gerede motorway Section, Turkey. The model requires two types of studies, namely: seismic hazard analysis and estimation of potential damage to structures based on damage probability matrices (DPM). The computations are carried out according to the proposed model by using the seismic hazard results and the best estimate DPM's developed in the study and the annual pure risk premiums are obtained for the different components of the motorway system by making a distinction between sections completed and sections under construction.

Keywords: Seismic hazard; Earthquake insurance; Damage probability matrix; Risk premium; Insurance premium; Gumusova–Gerede motorway

1. Introduction

Estimation of extreme seismic losses has been a major concern for the insurance sector. Over the last two decades a lot of effort has been devoted to the problem of how to devise reliable estimates of future earthquake losses, given the large uncertainties in the pattern of earthquake occurrence, both in time and space and our limited understanding of the behavior of vulnerable elements of the built environment. Especially, the recent series of large magnitude earthquakes have forced both the client and the insurance companies to obtain reliable estimates of potential seismic losses. Thus, developing statistical and probabilistic techniques to estimate

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the expected earthquake losses for important engineering structures become a major task for the insurance industry.

This article proposes a simple probabilistic model for the assessment of earthquake insurance rates for important engineering structures. The model integrates the information on seismic hazard and the information on expected earthquake damage on engineering facilities in a systematic way, yielding to estimates of the earthquake insurance premiums.

The proposed model is used to estimate the earthquake insurance premiums for the structures situated in the Bolu Mountain Crossing in the Gumusova–Gerede motorway section (BMC-GGMS), which is a part of the motorway project along Edirne–Istanbul–Ankara route, forming the main artery of the highway network in Turkey. The motorway system was hit by the Duzce earthquake of November 12th 1999 that caused damages at Viaduct-1 and the tunnel, for which the insurance company had to reimburse US$105 million for the losses of the client. After making such a high payment, the insurance company refused to renew the earthquake insurance coverage and since the new offer made by another insurance company was found to be too high, the client required a realistic evaluation of the pure risk premium. Thus, this study also aims the assessment of the earthquake insurance rates for the structures taking place at the Bolu Mountain Crossing in the Gumusova–Gerede motorway section.

2. Probabilistic model for the estimation of the earthquake insurance rates

The assessment of earthquake insurance rates requires two types of studies, namely: seismic hazard analysis and estimation of potential damage to structures. In the following, first a brief explanation is provided on these two types of studies and then the model is developed.

2.1. Seismic hazard analysis (SHA)

In the probabilistic sense seismic hazard can be defined as the probability of exceeding different levels of a selected earthquake "severity" or ground motion parameter at a given site and within a given period of time due to expected seismic activity in the region. Many models have been developed for seismic hazard analysis. Most of the earlier models of seismic hazard assessment were based on the assumption that earthquake occurrences are independent events in space and time, and utilized the Poisson model (also known as the classical SHA model) or the extreme value statistics. Later studies considered the temporal or spatial dependence of earthquakes only, like the renewal or Markov models. In recent studies, the occurrence of earthquakes is treated as a space–time process and the spatial and temporal correlations are taken into consideration. A detailed discussion of different stochastic models for seismic hazard analysis is given in Yucemen and Akkaya [1].

The probabilistic formulation adopted in this study is based on the time-dependent renewal model. The results obtained based on the classical SHA model are also presented and taken into consideration.

2.2. Estimation of the potential earthquake damage to structures

Another important component of the model is the assessment of damage to a specified type of structure as a result of earthquakes. Damage is commonly described by a loss ratio that varies with the strength of shaking and type of structure. Due to the uncertainties involved, the damage that may occur during future earthquakes has to be treated in a probabilistic manner. For this purpose damage probability matrices (DPM) can be constructed from observational and estimated data [2–5]. A DPM expresses what will happen to structures, designed according to some particular set of requirements, during earthquakes of various intensities. An element of this matrix $P_k(\mathrm{DS}, \mathrm{I})$ gives the probability that a particular damage state (DS) occurs when the structure of kth-type is subjected to an earthquake of intensity, I, where I denotes a selected earthquake "severity" or a ground motion parameter, like modified Mercalli intensity (MMI), magnitude, peak ground acceleration (PGA), spectral acceleration (SA), etc. The identification of damage states is achieved in two steps: