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Seismic hazard analysis of low seismicity NPP site

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ABSTRACT: This investigation provides the basis for evaluation of the adequacy of the seismic input data for the NPP site in a low seismicity region. Considering the fact that the seismic input generally results from data and processes of high uncertainty, the probabilistic approach has been used. The probabilistic approach involves definition of ground motion hazard curves on the basis of probabilistic seismic hazard analysis.

1 INTRODUCTION

For nuclear power plants sited within low seismicity regions, the seismic effects are mainly due to small earthquakes originating from their surrounding and stronger far distant earthquakes. Therefore, the seismic dynamic effect has an essentially different frequency content. The participation of low magnitudes results in predominantly high frequencies. This is the major difference in respect to standard spectra, determined on the basis of ground motion data of stronger earthquakes. Thus, in the seismic hazard analyses for such sites, it is necessary to determine the participation of the different magnitude ranges in the seismic hazard. The study is based on an actual site.

2 APPLIED METHODOLOGY

Nowadays, the probabilistic seismic hazard methodology has being generally adopted in the world for seismic risk evaluation, during construction of new and evaluation of existing structures. This applies particularly to special structures as the nuclear power plants are, for which the acceptable risk level against damage is rather low. On the basis of available documentation for the region around the site, compilation of the following maps has been carried out: epicentral map, neotectonic map and seismotectonic map of the wider region and the closer site surrounding. On the basis of the seismic and the neotectonic characteristics of the considered region, applying geological, geophysical and surveying data, re-interpretation of the contemporary tectonic activity has been carried out. Also, classification has been carried out of the fault structures: tectonic liniaments, tectonic knots and neovolcanic centres, according to their seismicity. For this purpose, we have used our experience in compliance with the world practice.In this way, transition from the analyzed, actual seismotectonic and geophysical observations towards forecasted, expected seismic sources in the considered region has been performed. On this basis, the following alternatives of the input parameters, which seismic hazard evaluation is based on, have been defined.

2.1 *Seismic source models*

To perform seismic hazard analysis, it is necessary to have defined its elements, one of which is the seismic source models. The seismic source models are defined by their geometry, the seismic activity, the activity rate in the range of magnitude of interest and maximum magnitudes of the earthquakes. From the seismotectonic investigations the seismic zones are determined as seismotectonic units with similar tectonic conditions for earthquake origination in them. Applying this principle, it is performed transition from zones of observed data towards geometrically determined prognostic seismogene sources, characterized by the maximum magnitude of the earthquakes expected in them. Presented in Fig. 1 are the mathematical models of the seismic sources for the analysis of the seismic hazard in this study. Only for the need of comparison, a case of simplified models of the seismic sources have been analyzed (Fig. 2).

The seismic activity is customarily defined by the recurrence relationships. In this study two alternatives for the recurrence equations are applied. According to the seismotectonic conditions, the source depth is taken at 10 km.

2.2 *Ground motion attenuation*

The investigations performed so far, have proved that the ground motion attenuation has significant effect upon the final results of the probabilistic seismic hazard analysis.

Therefore, for this site, according to the local geological conditions, three alternatives on ground motion attenuation equations have been selected. Also, during the selection, care has been taken for the magnitude range of interest and for the uncertainties which arise from data scattering.

2.3 *Treatment of uncertainties*

In this study, two types of uncertainties are taken into consideration. Random uncertainties are considered to be inherent in the physical processes from the present knowledge viewpoint. These uncertainties are integrated over according to the methodology. Here are the uncertainties of the individual earthquake realizations related to the magnitude, the site and the time as well as the scattering of data in the strong ground motion models. As the modelling uncertainties, in this study, they are accounted for by considering alternative choices of the input. Considered are alternatives affecting the determination of the hazard curves which are measures of the central value. Previously, sensitivity studies are carried out on the upper-bound magnitudes, on activity rates of the sources contributing the most to the hazard and to the focal depth. In this way, for the definition of the seismic hazard curves with central tendency, two alternatives for the seismic activity and three alternatives for the strong ground motion model have been applied. The mean accelerations are obtained by averaging the results from all the alternative seismic hazard analyses by taking equal weights for the two recurrence relationships and considering double weight of the first two attenuation laws in respect to the third one.

3. RESULTS OF THE SEISMIC HAZARD ANALYSIS

The probabilistic seismic hazard analysis has been performed according to the methodology and input data under Item 2. On the basis of the uncertainties consideration, alternative seismic hazard analyses have been carried out. The results from the seismic hazard analyses are hazard curves for peak ground acceleration and response spectra accelerations for T = 0.1, 0.2, 0.3, 0.4 and 1.0 sec. By an adequate presentation of the results obtained from the peak ground acceleration and the response spectra acceleration seismic hazard analyses, the uniform hazard response spectra are obtained. The mean uniform hazard response spectra obtained by averaging of all the considered alternative seismic hazard analyses are presented in Fig. 5. Also, in this figure is presented the standard spectrum US NRC R.G. 1.60, scaled to zero period acceleration with an annual probability of exceedence of 10^{-4}. The analyses of the seismic hazard for simplified seismic source models yield higher values.

In addition, seismic hazard analyses have been carried out in order to determine the participation of the individual magnitude ranges in the hazard. For this purpose, the seismic sources are divided into sub-sources of certain magnitude ranges (Fig. 3). Fig. 4 illustrates the hazard curves of such an alternative seismic hazard analysis. The results show that the participation of the lower magnitudes is predominant in the seismic hazard definition.

4 CONCLUSIONS

The seismic hazard of the considered site, which is within a low seismicity region, is characterized by predominant participation of lower magnitude earthquakes in the probability of exceedence of peak ground acceleration and spectral accelerations. Due to their lower frequency of occurrence and the distance, the earthquakes from the maximum magnitude range have relatively low participation. This conclusion is also proved by the fact that the uniform hazard spectra are lower than the standard design response spectra, defined on the basis of ground motion data from stronger earthquakes. The difference between these spectra increases with the frequency decrease.

The participation of magnitude ranges in the seismic hazard can be used for defition of the time duration of the design earthquake. The time duration should correspond to the magnitude range with the highest participation in the exceedence of the spectral acceleration in the vicinity of the fundamental vibration period of the NPP structure.

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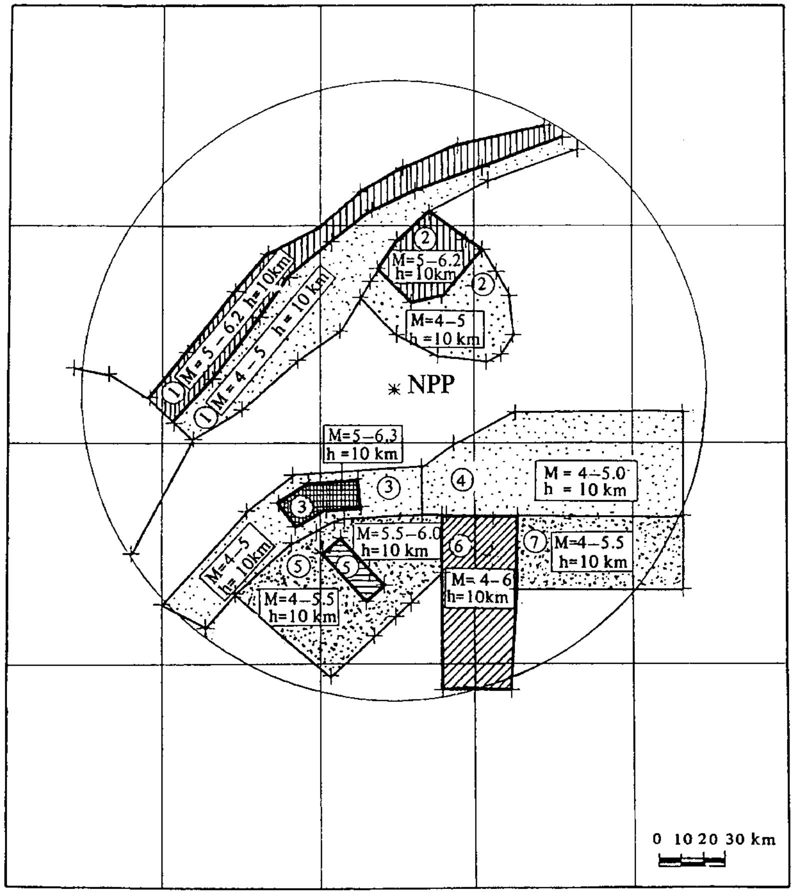

Fig.1. Mathematical model of seismic sources

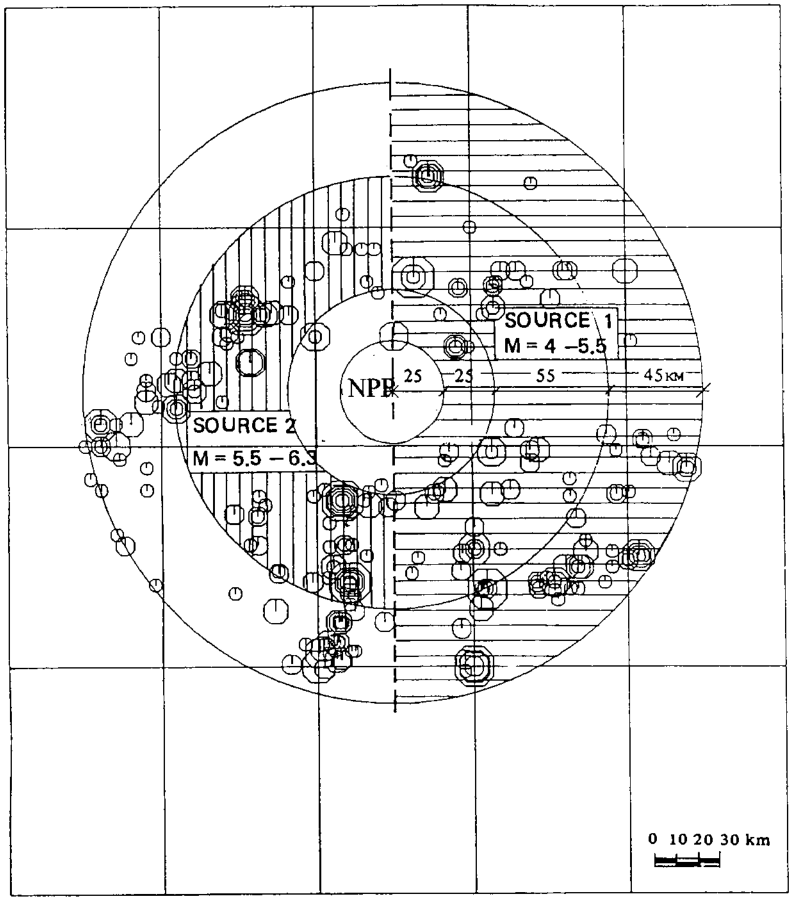

Fig.2. Simplified mathematical model of seismic sources

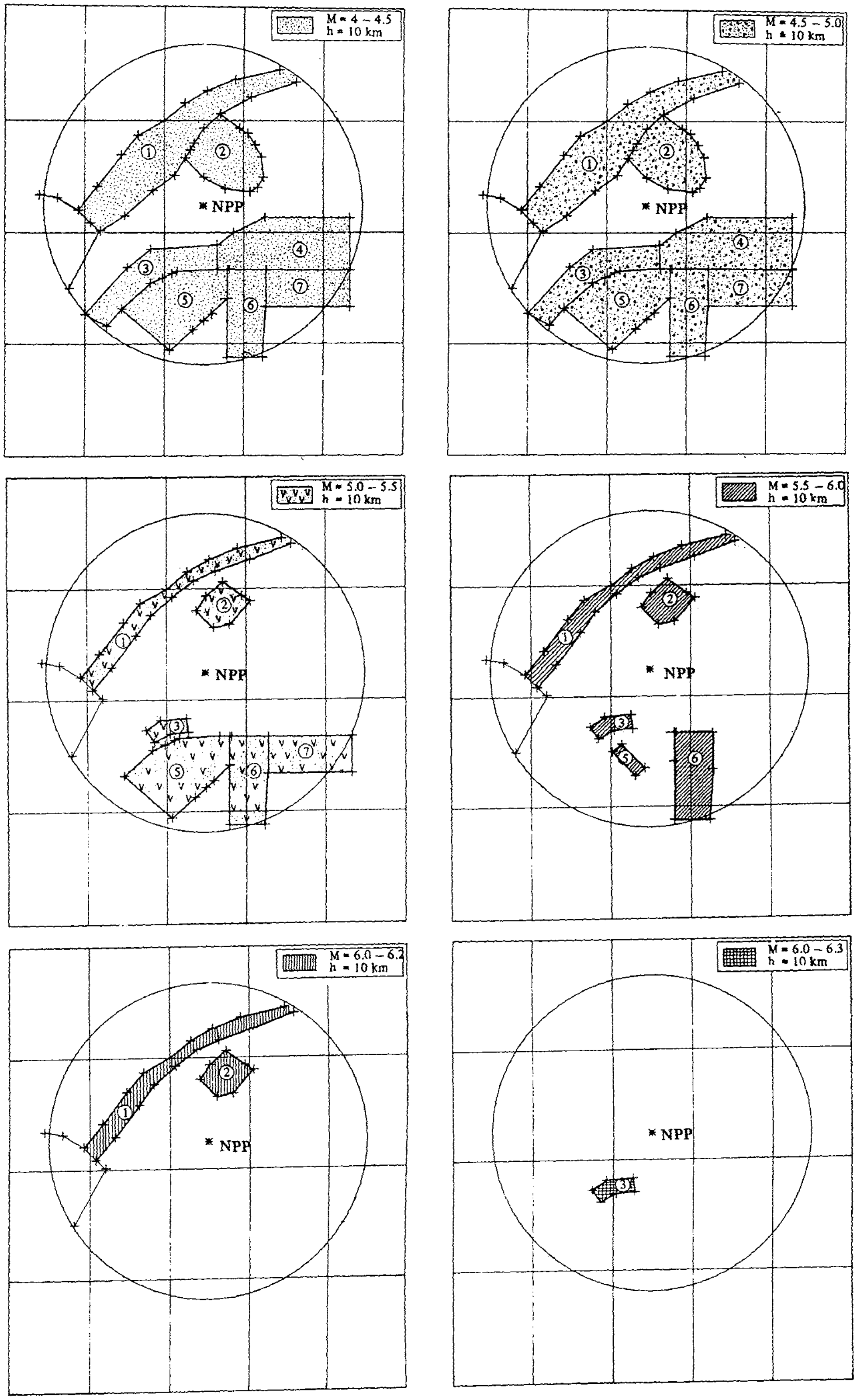

Fig.3. Mathematical model of seismic sub-sources

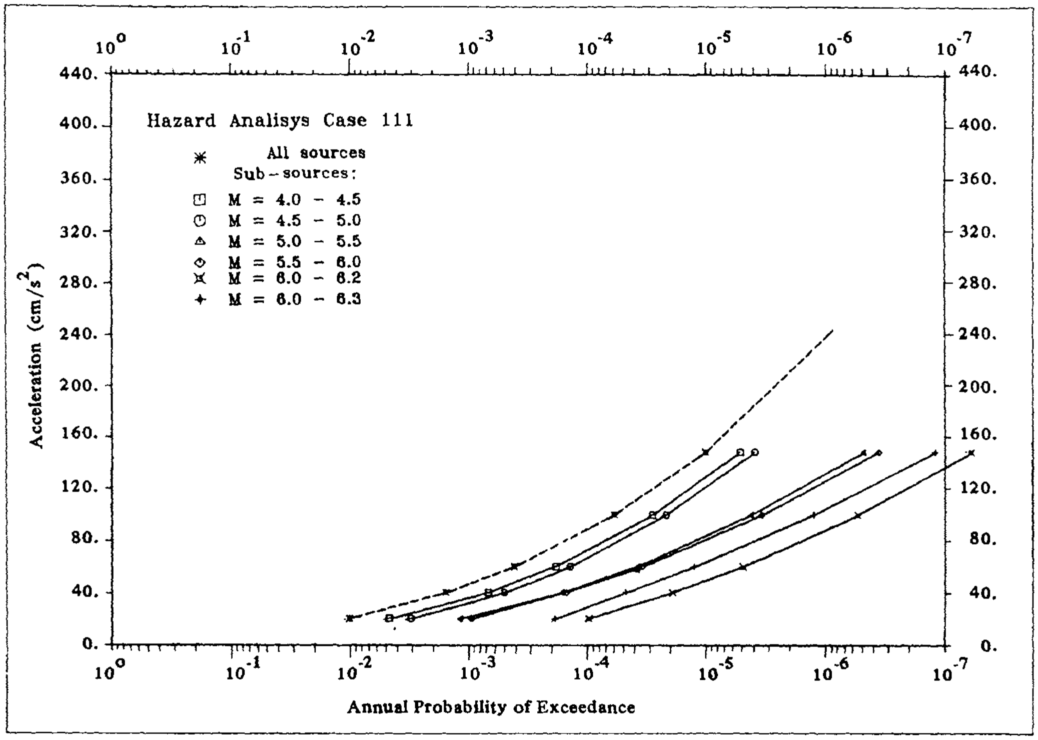

Fig.4. Hazard curves-hazard analysis case 111

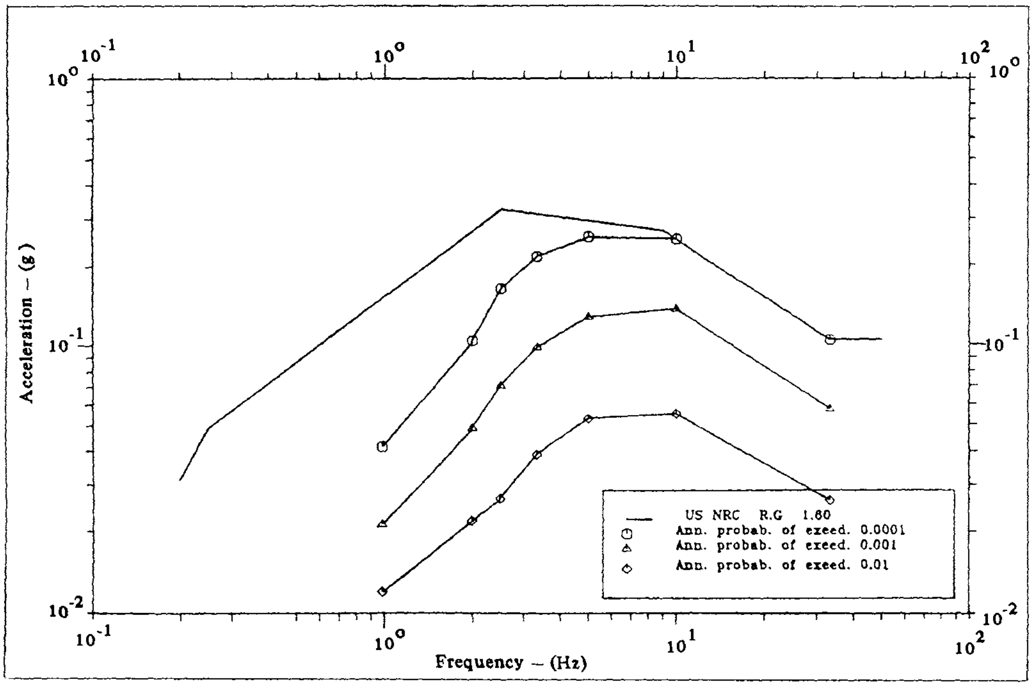

Fig.5. Mean uniform hazard response spectra

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