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An approximate assessment about seismic danger by sources threatening Bulgarian territory

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Summary
The mass media reports about seismic events in Bulgaria and surroundings generate a population interest about seismic danger for the territory of Bulgaria. Short presentation about the methods used by the specialists for the seismic zoning is summarized. A simple methodology proposed for the qualitative seismic danger assessment is presented by the expected intensities for average conditions (without considering attenuation lows, soil conditions, population density, etc.). A map for the mass media distribution and a Table with ellipsoid parameters reflecting light, middle and heavy damages is constructed showing the virtual intensities possibly generated by the local and external sources with M_{max} threatening Bulgarian territory.

Introduction

The seismic danger is a phenomenon interested to wide public due to the effects of strong earthquakes – destructions, deaths, injured people and huge losses. Frequently strong seismic events generated secondary effects also bringing losses of different type. The traditional assessments of the seismic danger have several directions. Earlier approach did seismic zoning on the base of observed intensities at a site, calculating repeatability and by extrapolation obtained so called seismic zoning maps. Frequently they are accompanied by seismic coefficient used by the engineers for antiseismic design and construction of the buildings and structures. More modern approach calculated the seismic acceleration creating maps used directly by the engineers and called seismic code maps for different time intervals (for example EUROCODE8 – 95- and 475-years recurrence time). Both approaches need initially the definition of the seismic sources represented by different way – sometimes like geometry figures, sometimes like ellipses of the stress ellipsoid projection. All described procedures are well developed and used by the professionals, but completely unknown and not easy understandable by the wide public. This frequently leads to speculations, mass-media deviation and unclear responses to population. The purpose of this study is to present by easiest way the approximate virtual maps, possible areas of expected destructions generated by the established seismic sources attributing to them so called M_{max} (maximum expected magnitude – parameter well known and accepted as reliable by all methods of seismic zonation). The seismic sources are presented as ideal ellipsoids and the areas of virtual strong, middle and weak destructions follow the form of the source. The model does not take into the consideration the soil conditions, the strength (type of construction, seismic design, etc.) of expected affected structure, the density of buildings and population, the time of occurrence of the seismic event (day/night), etc. The purpose if just to present the areas of virtual expected strong, middle and weak destructions. The accuracy of the model is less than 20%, but it is enough just to show to the wide public what and where the expected destructions are possible to occur in approximate way. The pictures build up are for use of the mass-media as illustrative material for the wide public. The virtual model does not pretend to be accurate and predictable. Its purpose is to be just to be illustrative, because frequently after every earthquake on the Balkans, the question “Is it dangerous for us?” arises and this question needs fast reply.

Methods of traditional ways for seismic zoning

The wide performed traditional ways to seismic hazard and risk assessment follows two main directions – Probabilistic and Deterministic:

- The Probabilistic approach needs statistical information about (possibly maximum) all historically and registered observed earthquakes influencing the selected site. The recurrence time is calculated and maximum observed intensities (accelerations) are considered. For the different time periods the interpolated and extrapolated expected intensities (accelerations) are determined. Usually, the maps

of seismic zoning are constructed for certain recurrence time with the respected level of non-exceedance. Almost always these maps are accompanied by the "seismic coefficient" numbers which are used for design calculations. These maps are base of the fundament of seismic zoning and for the codes and legal rules for engineering constructive works.

- The Deterministic approach needs the positions of the site and the seismic sources, the distances between them, the attenuation low of intensities (accelerations) as well as soil specific determinations (Vs30-for example). As a product seismic hazards maps are prepared giving numbers about the seismic danger of a site. Such approach is frequently used for the microseismic zoning and determination of design coefficients of vulnerable individual structures like NPP's, chemical dangerous factories, dams, etc.

During the last year a hybrid method is used, incorporating elements of deterministic and probabilistic approaches, believing this increases the accuracy and better assessment of the variability of the possible scenarios.

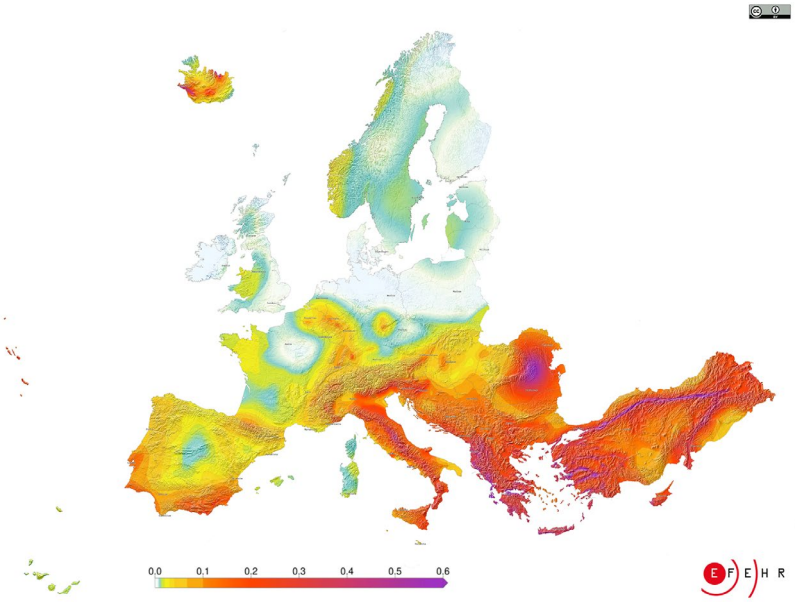


Figure 1. European probabilistic seismic hazard map for 10% probability of being exceeded in a specific time interval (i.e. 50 years) in terms of vertical PGA (peak ground acceleration) (http://www.efehr.org/earthquake-hazard/hazard-map/)

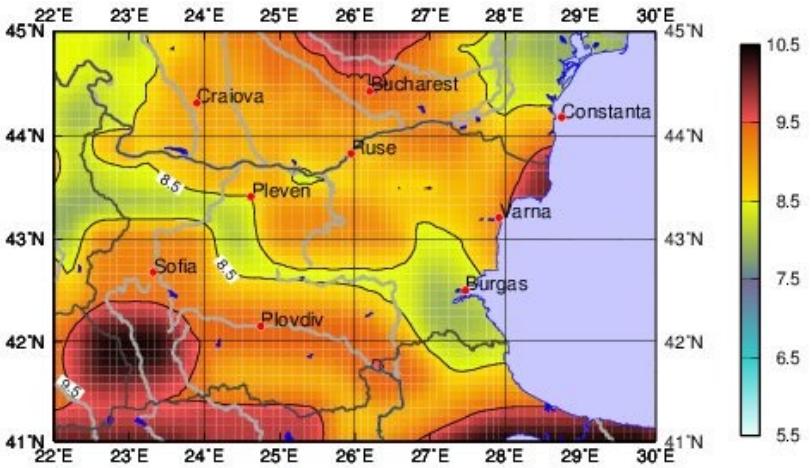


Figure 2. Seismic hazard from all source zones for a recurrence period of 10 000 years; colors represent intensities in MSK-1964 scale (as from 2006). (https://www.researchgate.net/publication/29629936_Probabilistic_seismic_hazard_map_for_Bulgaria_as_a_basis_for_a_new_building_code/figures?lo=1)

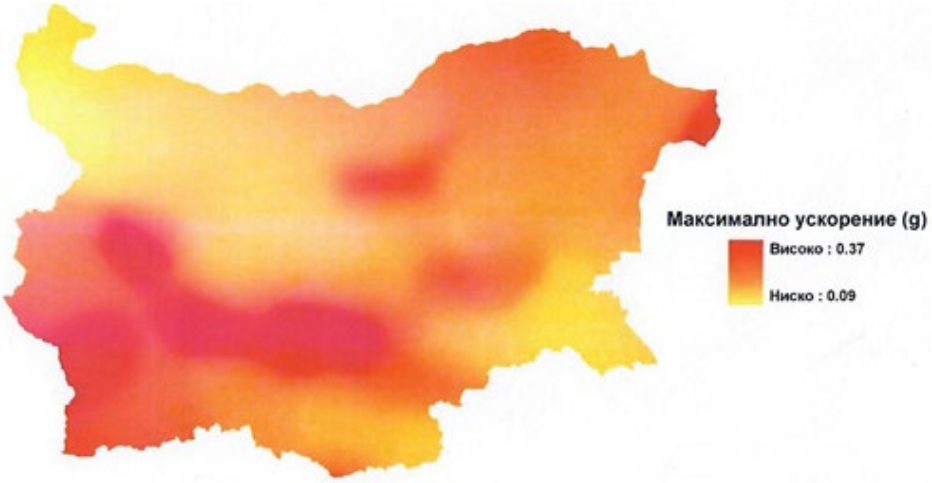


Figure 3. Seismic hazard map of Bulgaria in terms of PGA according the EUROCODE8 requirements.
(https://www.mrrb.bg/static/media/ups/articles/attachments/49e009007b78acf7a32f704216958b93)

The last version of the seismic hazard map of Bulgaria (Fig. 3) is even more confusing than previous.

New approach to seismic danger assessment for the public dissemination for population

The demonstrated seismic hazard maps used up to now (Fig. 1, Fig. 2, Fig.3) represented the seismic danger in units well familiar to specialists and absolutely not understandable for the journalists, mass-media and population. To avoid the huge confusion related to the use of different approaches, results, maps and confusing units, we suggest to use a simple approach and to present in virtual, but more visual and understandable way the expected seismic danger due to the strong earthquakes with magnitudes between 5 and 7.0 ($5.0<M<7.0$) This magnitude interval is selected because smaller seismic events ($M<5.0$) does not represent a risk for the population and infrastructure. The larger earthquakes ($M>7.0$) frequently are more complicated, generate secondary events which is difficult to assess and have much more complicated influence to the population and infrastructure. Their effects strongly depend on the type of earthquake, seismic energy release, soil conditions, structural peculiarities, etc., that is practical impossible to have a satisfactory accuracy to predict their negative influence. Considering these peculiarities, we presented the approximate virtual expectations about the seismic danger, depending on the source orientation accepted reasonably due to the macroseismic effect demonstrated by past earthquakes, not considering soil conditions and buildings structural design and only giving the approximate distances covered by light, middle and heavy destructions threatening the population. This approach is to present easy the expected possible negative effects from sources located on the territory of Bulgaria, including as well as some sources located outside the country but possess possible destructions in Bulgaria. The Vrancea source in Romania needs special treatment, because of the specific behavior – larger depth, which means larger area of negative influence, specific energy release in southeast direction (Bulgaria territory) and wider spectral content more dangerous to the high buildings. This approach was applied and the following map was constructed (Fig. 4).



Figure 4.Seismic sources threatening Bulgarian territory (Vrancea-Romania excluded) presented by red line (thin), areas with heavy destructions (magenta), middle (orange-thin) and light (green line) damages. Numbered sources with expected (M_{max}): Internal: 1-Shabla-Kaliakra (7.5-8.0); 2-Gorna Oriahovica (7.0); 3-Sofia (6.5); 4-Kjustendil (6.0); 5-Plovdiv (7.0); 6-Kresna-Kroupnik (7.5-8.0); External: 7-Kopaonik (6.0); 8-Skopie-Valandovo (6.0-6.5);9-North Greece (7.0); 10-Edirne (6.0); 11-North Anatolian Fault (7.0-8.0).

Table 1. Seismic sources, short and long semi axes of the ellipsoid limitation the light (40-50%), middle (50-60%) and heavy (60-80%) damages.

Source	Long semi ax [km] (light)	Short semi ax [km] (light)	Long semi ax [km] (middle)	Short semi ax [km] (middle)	Long semi ax [km] (heavy)	Short semi ax [km] (heavy)
№ 1	50-60	25-40	20-30	15-20	15-20	10-15
№ 2	30-40	20-30	20-30	15-20	14-17	10-12
№ 3	20-30	20-30	15-20	15-20	10-12	10-12
№ 4	20-30	20-30	15-20	15-20	10-12	10-12
№ 5	30-40	20-30	20-30	15-20	14-17	10-12
№ 6	50-60	20-30	20-30	10-20	15-20	10-15
№ 7	20-30	20-30	15-20	15-20	10-12	10-12
№ 8	20-30	20-30	15-20	15-20	10-12	10-12
№ 9	30-40	20-30	20-30	15-20	14-17	10-12
№ 10	20-30	20-30	15-20	15-20	10-12	10-12
№ 11	120-150 aggr.	60-70 aggr.	40-60aggregate	30-40aggregate	15-20 (each)	10-15 (each)

Conclusions

A scheme of virtual possible ellipses outlining the seismic sources, areas of heavy, middle and light damages, expected in case of M_{max} seismic event occurred in the respective source.
The parameters of the ellipses are presented in a table for faster references of distances with expected light, middle and heavy damages in case of strong earthquakes, occurred in the seismic sources (on the territory and outside) threatening Bulgaria.

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