AIRPORT CONDITIONS IN MACEDONIA: SEISMIC RISKS

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Abstract. The territory of the Republic of Macedonia is located in the Balkan region – one of the most earthquake prone areas in Europe. Investigations of the seismicity of the Balkan Peninsula point out that this territory is exposed not only to autochthonous earthquakes but also to earthquakes from adjacent seismically active areas. The Macedonian Seismological network (SORM) and the network of the Institute of Earthquake Engineering and Engineering Seismology (IZIIS) detect, monitor and give detailed information on seismicity of the region. Their information directly impacts the accuracy of seismic hazard assessment. Application of statistical models of the "proposed future" seismic activity of the territory under investigation is of crucial importance in seismic hazard assessment. If the concept of "seismicity" indicates a measure with which natural seismic activity is determined in certain areas/sites (airports, flying fields etc.), it is of great importance in determining: 1) values of maximum expected intensity and ground accelerations of earthquakes and 2) given return periods (in years). The results of the research are presented on Seismic hazard maps for the areas with airports, airfields, and flying field sites. The parameter used as a measure of the seismic hazard for the areas under consideration, is the PGA, peak ground acceleration, (values of acceleration of *g* with a 64% probability to exceed).

Keywords: seismicity, seismic hazard, seismic risk

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1. Introduction

Defining the parameters of ground motion during earthquakes (macroseismic intensity, displacement, velocity, acceleration etc.) and their application in determining seismicity parameters is of great interest.

Considering the random nature of an earthquake occurrence, modeling it is difficult without simplifications and assumptions related to the earthquake occurrence mechanism and structural behavior under seismic effects.

One way of presenting the earthquake loading for a given geographical region is with a seismic hazard map. Therefore, hazard mapping techniques must relate seismological and engineering parameters.

We present two hazard models, in order to show the effect of the mathematical/statistical approach to seismic hazard estimation. The maximum expected intensity and the peak ground acceleration (PGA) are used as a measure of the seismic hazard for the territory of Republic Macedonia.

2. Data

The territory of Republic of Macedonia was included in the seismic hazard investigations of the Euro-Mediterranean area. It is clear that the territory of the Republic of Macedonia and neighboring countries are within a prominent active seismic area of the Balkan Peninsula. This area is also exposed to earthquakes from adjacent seismically active areas (Figure 134).

The data for the study comes from records of seismic events from 1900 to 2000, isoseismal maps, and additional graphical and numerical results. These data are contributions of various research projects of the observed seismic activity on the territory of Republic of Macedonia. Besides the seismological data, available tectonic and engineering/seismological data for this area were also used. In this way, the existence of several well defined seismogenic zones (Vardar, Drim, Struma, and others), were defined. Extremely high activity has been identified in these zones where, during the neotectonic stage, intensive transformations of the old structures have taken place. The map of maximum calculated earthquake magnitudes is the result of such detailed investigations of the territory of the Republic of Macedonia. It is crucial to the seismic hazard investigations of the territory under consideration.

Comparing the seismological data and the tectonic conditions, a close relationship between the seismogenically active areas and the tectonic knots of faults (faults in different directions) is evident (Skopje, Valandovo, and other seismic areas). The magnitude of earthquakes in these zones depends upon whether the knots are created by an intersection of regional or local faults (Figure 135, Table 28, Jordanovski Lj, Pekevski, L. et al, 1998). This relationship is clearly presented on the map of maximum observed macroseismic intensities on the territory of the Republic of Macedonia for the period 1900-2000 (Figure 136).

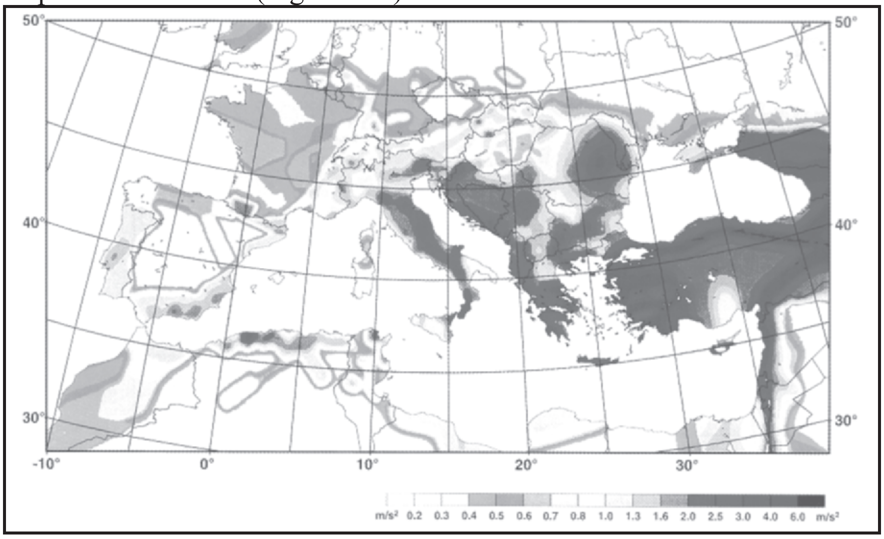

Figure 134. Seismic hazard assessment of the European-Mediterranean area in terms of peak ground acceleration for 90 % of non exceedance within a 50 year period. Red and brown colors indicate areas with the highest seismic hazard values. A significant part of the Republic of Macedonia belongs to the area with high seismic hazard values (Grunt Hal et al. 1999).

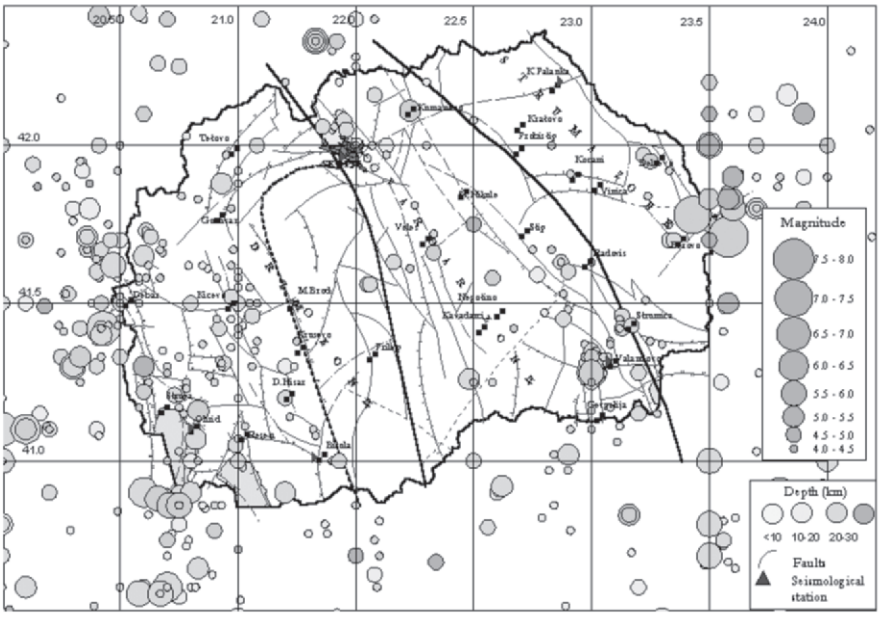

Figure 135. Epicenter map of earthquakes (1901-2000).

Table 28. The most significant historic and recent earthquakes occurred in the territory of the Republic of Macedonia and neighboring areas.

Year	*M.*	*D.*	h	min	s	φ	λ	*h*	*M*	I_0	*Epicentral area*
			(UTC)			(^{0})	(^{0})	(km)		(MSK-64)	
(400)						41.50	22.00		6.1	9	*Gradsko (Stobi)*
518						42.10	21.40		6.1	9	*Skopje (Skupi)*
527						41.10	20.80		6.1	9	*Ohrid Lake*
896	9	4				41.70	23.00		6.1	9	*Pehcevo - Kresna*
1555						42.00	21.50		6.1	9	*Skopje*
1755	2	26				42.50	21.90		6.1	9	*Urosevac (Kacanik)*
1904	4	4	10	2	38.1	41.78	22.93	25	7.3	9	*Pehcevo - Kresna*
1904	4	4	10	25	50.0	41.71	23.08	30	7.8	10	*Pehcevo - Kresna*
1905	10	8	7	28	51.4	41.80	23.10	30	6.5	8	*Pehcevo - Kresna*
1911	2	18	21	35	18.0	40.86	20.71	25	6.7	9	*Ohrid Lake*
1912	2	13	8	4		40.86	20.75	25	6.0	8	*Ohrid Lake.*
1921	8	10	14	10	40.0	42.30	21.40	20	6.1	9	*Urosevac (Vitina)*
1931	3	7	0	16	44.8	41.28	22.50	25	6.0	8	*Valandovo*
1931	3	8	1	50	24.0	41.28	22.50	10	6.6	10	*Valandovo*
1942	**8**	**27**	**6**	**14**	**15.6**	**41.62**	**20.47**	**15**	**6.0**	**9**	***Peskopia***
1963	7	26	4	17	11.7	42.02	21.42	5	6.1	9	*Skopje*
1967	11	30	7	23	49.9	41.42	20.43	20	6.5	9	*Debar region*

3. SEISMIC HAZARD MODEL FORMULATION

The construction of the seismic hazard models of the Republic of Macedonia is based upon the statistical evaluation of the past seismic activity combined with the geological setting. Different types of input data are needed to develop a reasonable model. They are:

- Geological setting. Location and behavior of the faults.
- Seismicity and source location.
- Maximum credible events for each source.
- Isoseismal maps of the selected earthquakes, for estimation of maximum expected magnitude and maximum intensity (according to the theory of extremes).
- Recurrence relationship.
- Attenuation relationship.
- Probabilistic model of seismic occurrences.

All information on the seismic history, geological structure, frequency of earthquake occurrences, and attenuation of ground motion with distance from the epicenter is used in the model to obtain the probable future seismic ground motion.

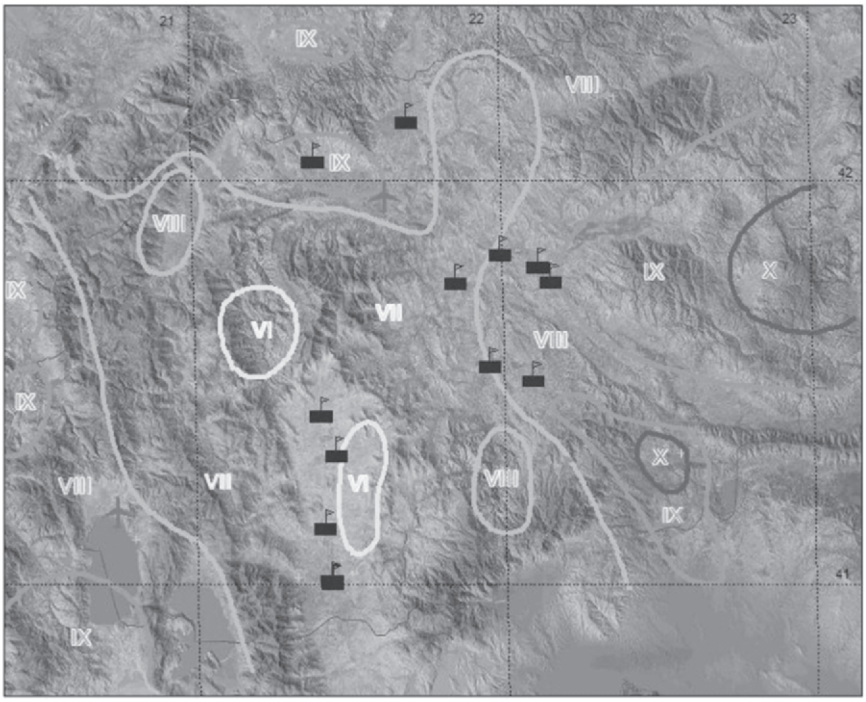

Figure 136. Map of maximum observed intensities (MCS) in the territory of the Republic of Macedonia (1901-2000).

Seismic hazard maps for the Republic of Macedonia for future time periods and different seismicity models are obtained using the above input and described procedures, (earthquake ground motion parameter forecasting). The hazard is measured in terms of maximum expected intensity and peak ground acceleration.

4. Results of hazard analysis

For enhanced flying and airport safety, seismic hazard maps (Figure 139) have been generated for areas where airports (AP, pink), airfields (AF, blue) and flying fields (FF, green) have been built. The parameters used as measures of the seismic hazard are the maximum expected intensity of the "future" earthquakes, and the PGA, values of acceleration of *g* with 64% probability to exceed in certain return periods (in years).

4.1. THEORY OF EXTREMES

Another seismic hazard parameter, as well as the characteristics of the regional seismicity, is the intensity of the maximum expected earthquakes macroseismic effect I_{exp} in a certain return period T (in years). The extreme values method (Jenkinson's solution of the stability postulate) has been applied for the determination of I_{exp} (Pekevski, 1992)

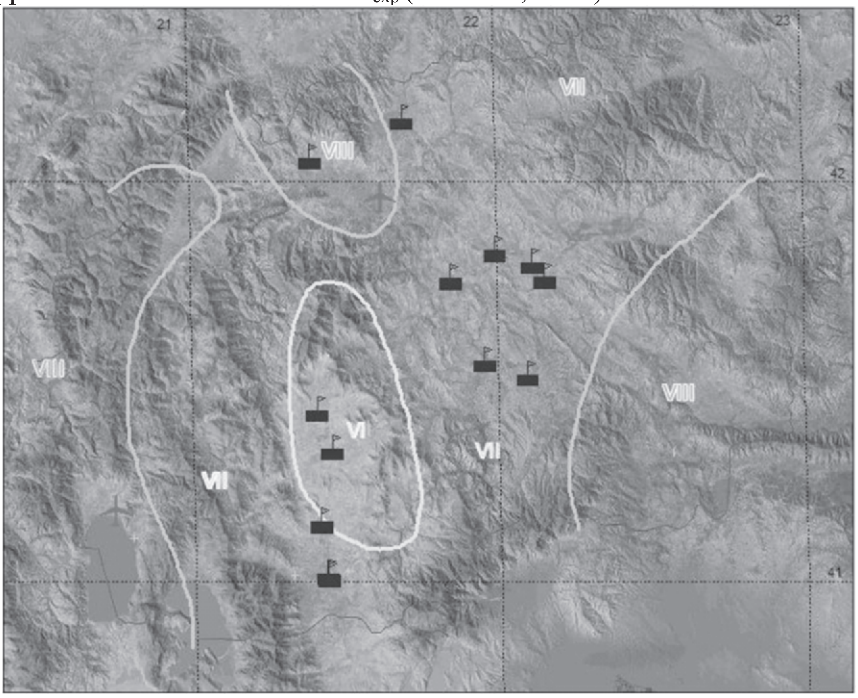

Figure 137. Theory of extremes (Jenkinson's solution) Expected intensity Imax in a 100 year period.

The results are presented on the Figure 137 and Figure 138. The seismogenic areas with high seismic activity are separated out by the isolines of certain MCS intensity. This procedure was used in research of the seismicity on the territory of former Yugoslavia (Pekevski, 1983, Ribaric et al., 1987).

4.2. PROBABILISTIC HAZARD

Figure 139 shows the seismic plane sources map of the Republic of Macedonia and AP, AF, and FF sites. Applying the model of plane seismic sources and the probabilistic approach, the calculated seismic hazard (for the grid points of the territory under investigation) in return period of 100 years, is presented on Figure 140.

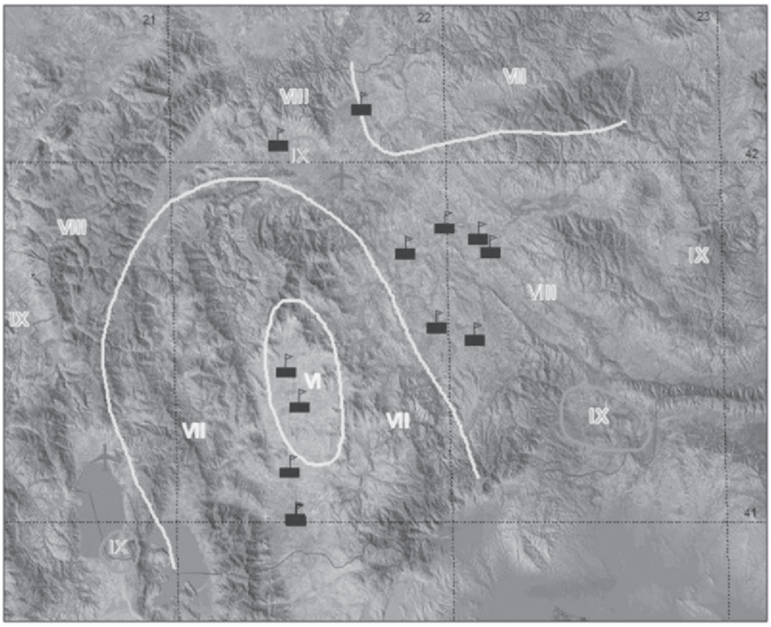

Figure 138. Theory of extremes (Jenkinson's solution): expected intensity Imax in a 200 year period.

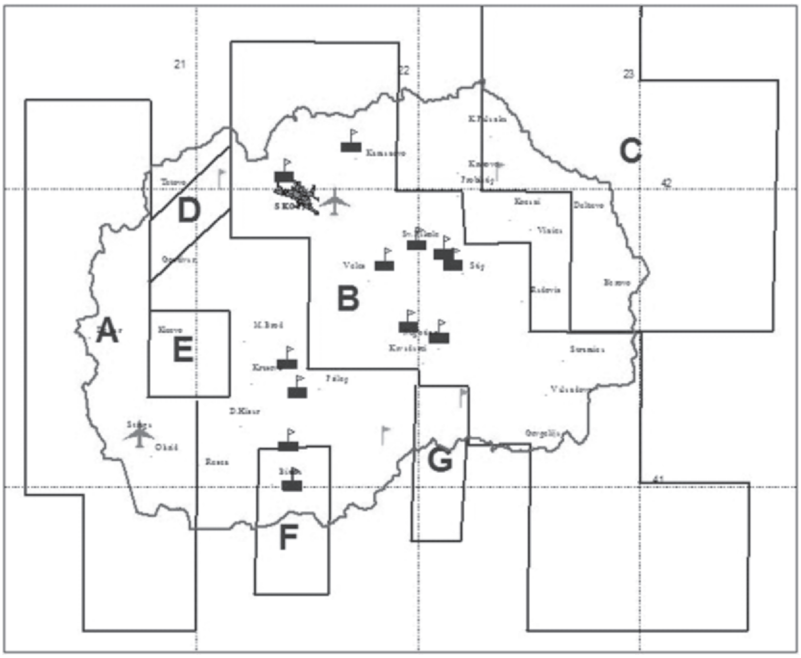

Figure 139. Map of plane sources (according to the seismological data) on the territory of the Republic of Macedonia.

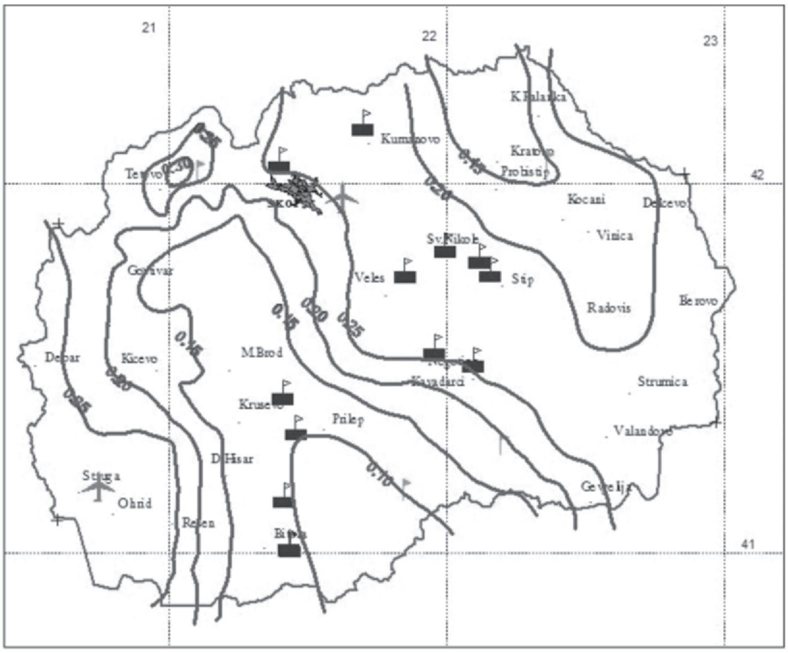

Figure 140. Probabilistic model: plane sources, return period 100 years.

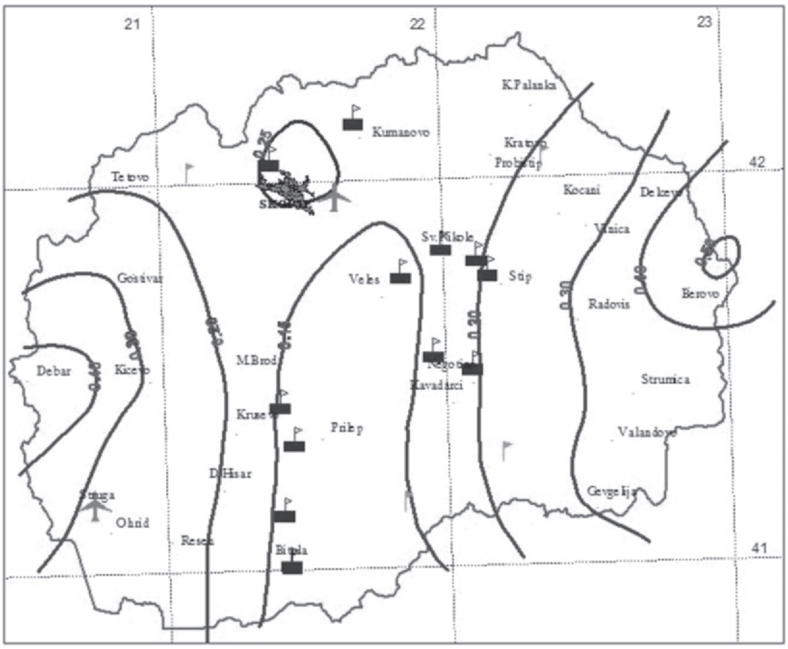

Figure 141. Probabilistic model: plane sources, return period 100 years.

Changing the model's seismic source type (line instead of plane) produces an evident difference in g-contour lines and in iso-acceleration contour lines as well, for the same return periods (100 years) and PGA values, with a 64% probability to exceed (Figure 141).

Comparison of these maps shows the effect of the *form/nature* of the seismic sources on the shape of the g-contour. The general shape of g contours depends on the groupings of earthquakes produced by different seismic sources (Mihailov D, Dojcinovski D., 1992).

5. Conclusion

The differences between the values of peak ground acceleration (PGA) for different types of seismic sources for the airports (AP), flying fields (FF), and airfields (AF) under investigation, show the need to study source modeling approaches, based not only on the historical seismological data but also on the specific tectonic conditions of the territory of the Republic of Macedonia, as well as on the analysis of recent seismic activity.

The results of this research will impact decision making on acceptable seismic risk levels for the safety of the AP, FF and AF sites.

References

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