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Seismic microzoning parameters for urban development planning based on damage control criteria

Tomislav Petrovski

Research Assistant, Ss. Cyril and Methodius University in Skopje, Republic of Macedonia, Institute of Earthquake Engineering and Engineering Seismology IZIIS, *tomijp@iziis.ukim.edu.mk*

Abstract

The abstract In the past thirty years, significant efforts have been made toward establishment of uniform criteria for empirical performance evaluation based on earthquake damage classification and seismic evaluation of buildings. Developed empirical performance criteria have been used in many countries for estimation of physical, functional and economic losses, planning for reconstruction of earthquake stricken regions, or simulation of expected earthquake losses for different level earthquake hazard scenarios, disaster preparedness planning and planning for seismic risk reduction. Recently, quantified performance evaluation based on inelastic response analysis of structural systems and dominant nonstructural components has been used. Implementing damage control criteria, seismic hazard parameters in seismic microzoning for urban development planning and design of buildings have been developed for the Planning Scale-, the Maximum Considered- and the Frequent Scale- Earthquake scenario. For the considered earthquake scenarios, modification of vibrational characteristics such as dominant ground vibration periods, peak ground acceleration, spectral acceleration and relative velocity have been analysed for the selected urban area and the specific local soil conditions, considering low, medium and high rise buildings. Mapping of earthquake hazard parameters based on damage control criteria is presented and recommended for implementation in urban development planning.

Key words: expected earthquake losses, earthquake hazard scenarios,damage control criteria

1 Seismic hazard

Seismic hazard is defined as the probable level of ground shaking associated with the recurrence of earthquakes. The assessment of seismic hazard is the first step in the evaluation of seismic risk, obtained by combining the seismic hazard with vulnerability factors (type, value and age of buildings and infrastructures, population density, land use, date and time of the day). Frequent, large earthquakes in remote areas result in high seismic hazard but pose no risk; on the contrary, moderate earthquakes in densely populated areas entail small hazard but high risk. The basic elements of modern probabilistic seismic hazard assessment can be grouped into four main categories:

1.1 Earthquake Catalogues and Databases

The compilation of a uniform database and catalogue of seismicity for the historical (pre - 1900), early - instrumental (1900 - 1964), and instrumental periods (1964 - today).

1.2 Earthquake Source Characterization

The creation of a master seismic source model to describe the spatial – temporal distribution of earthquakes, using evidence from earthquake catalogues, seismotectonics, paleoseismology, geomorphology, mapping of active faults, geodetic estimates of ristal deformation, remote sensing, and geodynamic models.

1.3 Strong Seismic Ground Motion

The evaluation of ground shaking as a function of earthquake size and distance, taking into account the propagation effects in different tectonic and structural environments and using direct measures of damage caused by the earthquake (the seismic intensity) and instrumental values of ground motions.

1.4 Computation of Seismic Hazard

The computation of the probability of occurrence of ground shaking in a given time period, to produce maps of seismic hazard and related uncertainties at appropriate scales.
Seismic hazard maps depict the levels of chosen ground motions that are likely to be or not to be exceeded at the specified exposure times. Hazard assessment programs commonly specify a 10 % chance of exceedance (90 % chance of non - exceedance) of some ground motion parameter for an exposure time of 50 years, corresponding to a return period of 475 years.
This Global Seismic Hazard Map depicts Peak Ground Acceleration (PGA) with a 10 % chance of exceedance in 50 years. The site classification is rock everywhere except Canada and the United States, which assume rock and (or) firm soil as referent ground conditions. PGA, a short - period ground motion parameter that is proportional to force, is the most commonly mapped ground motion parameter because current building

codes that include seismic provisions specify the horizontal force a building should be able to withstand during an earthquake. Short - period ground motions affect short - period structures (e.g., one - to two - story buildings, the largest class of structures in the world). This GSHAP map depicts the likely level of short - period ground motion from earthquakes in a fifty - year window. The map colors chosen to delineate the hazard roughly (Figure 1.1.) correspond to the actual level of the hazard. The lighter colors represent lower hazard while the darker colors represent higher hazard. Specifically, white and light grey correspond to low hazard (equivalent to 0 % - 8 % g, where g equals the acceleration of gravity); 0.4 PGA to1.6 PGA corresponds to moderate hazard (8 % - 25 % g); 2.4PGA to 4.0 PGA corresponds to high hazard (25 % - 40 % g); and 4.0 PGA to 5.0 PGA corresponds to very high hazard (>40 % g). In general, the largest seismic hazard values in the world occur in areas that have been, or are likely to be, the sites of the largest plate boundary earthquakes.

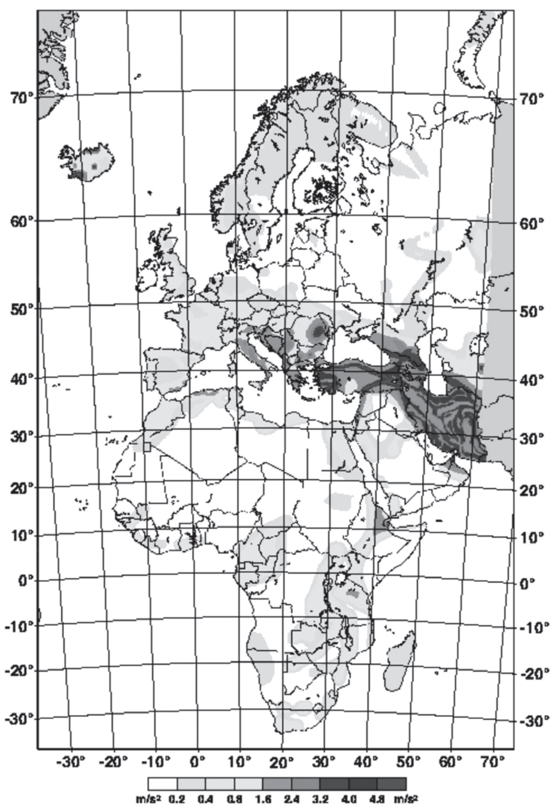

Figure 1. Horizontal PGA seismic hazard map representing exceedance of 10 % within 50 years for the whole greater GSHAP area covering Europe, the Mediterranean, Africa, and the Middle East (Anali di Geofizika, Volume 42, No. 6, December 1999)

2 Compilation of the global seismic hazard map

In order to mitigate the risk associated with recurrence of earthquakes, the GSHAP fostered a regionally coordinated, homogeneous approach to seismic hazard evaluation. The GSHAP strategy was to establish a mosaic of regions led by selected regional centers and multinational test areas under the coordination of large working groups. Some areas, specifically the Mediterranean and the Middle East, were included in several overlapping projects. In addition, the GSHAP allied with existing hazard projects to avoid duplications and strengthen cooperation across borders (e.g., in the Balkans and the Near East). Working groups of national experts representing different disciplines required for seismic hazard assessment were assembled for each region or test area. These working groups produced common regional earthquake catalogues and source characterizations, and compiled or computed regional hazard values. In some cases (parts of Africa, the Western Pacific, and North America) the GSHAP hazard map was derived from published materials. Finally, an editorial committee supervised the integration of the results of all the regional projects into the Global Seismic Hazard Map.
The PGA data were combined with a shaded relief base map using Arc/Info 7.2.1 geographic information system (GIS), software. The cell size of the PGA and relief based grids is 0.0833 degrees.

3 The global seismic hazard assesment program – GSHAP

The Global Seismic Hazard Assessment Program (GSHAP) was launched in 1992 by the International Lithosphere Program (ILP) with the support of the International Council of Scientific Unions (ICSU), and endorsed as a demonstration program within the framework of the United Nations International Decade for Natural Disaster Reduction (UN/IDNDR).
Minimization of loss of life, property damage, and social and economic disruption due to earthquakes depends on reliable estimates of seismic hazard. National, state, and local governments, decision makers, engineers, planners, emergency response organizations, builders, universities, and the general public require seismic hazard estimates for land use planning, improved building design and construction (including adoption of building construction codes), emergency response preparedness plans, economic forecasts, housing and employment decisions, and many more types of risk mitigation. GSHAP was designed to provide a useful global seismic hazard framework and serve as a resource for any national or regional agency for further detailed studies applicable to their needs. GSHAP cooperated with a number of international organizations, including the International Association of Seismology and Physics of the Earth Interior (IASPEI), UNESCO, the International Association of Earthquake Engineering, and the World Meteorological Organization.

Financial support from NATO, ILP, ICSU, UNESCO, IASPEI, the European Council, the European Union, the International Geological Correlation Program and INTAS is acknowledged. Many national agencies supported or participated in the GSHAP. The insignia of primary contributors appear on the map. Some proprietary software for hazard computation (FRISK88M) was supplied freely to GSHAP by R. McGuire.

4 Dominant freqency content and spectral charcteristics of distant earthqakes

For assessment of dominant frequency content of distant earthquakes, two representative earthquake records obtained on strong motion accelerographs have been selected for consideration.
First, the Bucharest record of March 04, 1977 Vranchea earthquake, obtained at epicentral distance of 110 km. and second, the SCT1 record of the September 19, 1985 Mexico Earthquake, obtained in Mexico City at a distance of about 400 km from the causative fault triggered in the subduction zone at the Pacific coast of Mexico.
The Bucharest record of March 04, 1977 Vranchea Earthquake in Romania was obtained in the basement of a one story reinforced concrete frame building located at the Building Research Institute in the north-eastern part of the city, on over 100 meters deep alluvial sediments of fine and coarse sand, silt and clay.
The recorded peak ground acceleration of the N-S component was 0.20g amplified by local site effects, the calculated maximum relative velocity response spectra was Sv=130 cm/sec (Figure1.2.), while the absolute acceleration response spectra was Sa=600 cm/s^2 for the dominant ground vibration period of T=1.5 sec. and 5 % damping for the N-S component of the Bucharest record. Presented dditionally in Figure1.1. is the relative velocity response spectra of the Vrancehea earthquake record obtained in the city of Nish, at an epicentral distance of 440 km. on deep alluvial sediments.
The maximum value of the relative velocity response spectra of the record in Nish for the E-W component and 5 % damping is Sv=35 sm/sec for a dominant vibration period of about 2.0 sec.
The Mexico City record of September 19, 1985 Mexico Earthquake was obtained in the basement of the SCT building located on 30 m. deep soft silty clay deposits in the lake bed zone, representative of heavily damaged high-rise buildings in Mexico City due to the pronounced amplification of bedrock ground motions by the soft silty clay deposits with a shear wave velocity of 80-100 m/sec.
The calculated maximum relative velocity response spectra for the N-S component was Sv=180 cm/sec. (Figure1.2) and the absolute acceleration response spectra was Sa=500 cm/s^2 for 5 % damping and a dominant ground vibration period of T=2.1 sec.
It is evident from the presented distant earthquake records that, in the case of relatively low peak ground acceleration in the range of 0.13 to 0.20g, the relative velocity and absolute acceleration response spectra could be in the range of Sv=130-180 cm/sec, and Sa=500-600 cm/s^2, respectively.

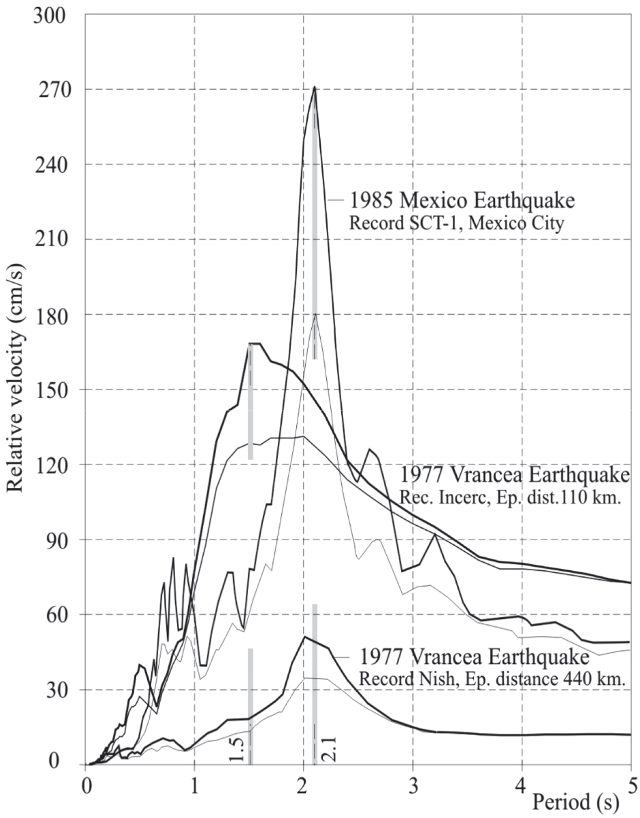

Figure 2. Relative velocity, response spectra of distant earthquakes

5 The Manjil earthquake of June 20, 1990 in Northern Iran

In the centuries long earthquake history of Iran, one of the most devastating Manjil Earthquake occurred on June 20, 1990, with a magnitude of Ms = 7.4 and an estimated epicentral intensity of IX - X degrees of MM Scale, causing 13,911 deaths, 36,693 people treated for injuries and over 8,000 people badly injured taken for hospitalization in Tehran. Damage and losses to the built environment were extremely high, estimated at 4.77 billion dollars in the densely populated region of the provinces of Gilan, Zanjan and Eastern Azerbaijan.

The area of damaging effects, with ground acceleration larger than 10 % g, was estimated to 49,574 square kilometers (Figure 1.3) affecting 3,152 villages and 45 towns and cities. More than 214,000 residential units, 1,329 school buildings, over 300 health units as well as 82 medical centers and hospitals, a large number of agricultural land and facilities, religious and administrative units, service centers including 68 factories were destroyed or heavily damaged.

Over 500,000 families were left homeless and 178 village locations were abandoned due to landslides and other ground instabilities. In the city of Rasht, at a distance of 60 km. from the causative fault, a large number of tall buildings and elevated water reservoirs experienced failure and severe damage, exposed to amplified ground accelerations due to water saturated sandy soil deposits. In the Caspian plain, at a distance 50 to 80 km. from the causative fault, liquefaction of loose sand and silt layers occurred in an area of 650 square kilometers along the coast, exposed to accelerations of 0.10-0.20g (Figure 1.3).

6 Earthquake hazard parameters for the Seismotectonic Provinc of Iran

Earthquake hazard analysis requires assessment of earthquake hazard parameters such as the maximum expected magnitude, M_{max}, the activity rate l, and the b value of the Gutenberg-Richter relation. These parameters have been evaluated for each seismotectonic province of Iran. The maximum likelihood method has been applied (Kijko and Sellevoll, 1992), allowing the combination of both historical and instrumental data. The maximum likelihood estimation of the seismicity parameter b adapts well to the Iranian earthquake data, due to the fact that earthquake magnitudes have always been reported with associated uncertainty. In this method, artificially homogeneous data are also simulated, through the determination of the completeness period over which data in a given time span were reported. In the present study, unlike the previous works on Iran, seismic gaps (i.e. when records are missing or the seismic network was not in operation) and uncertainties related to the earthquake magnitudes are considered in the analysis. This is necessary for a region like Iran where few earthquake data are available. In this work, the Gutenberg-Richter parameters were assumed to be constant for each province.

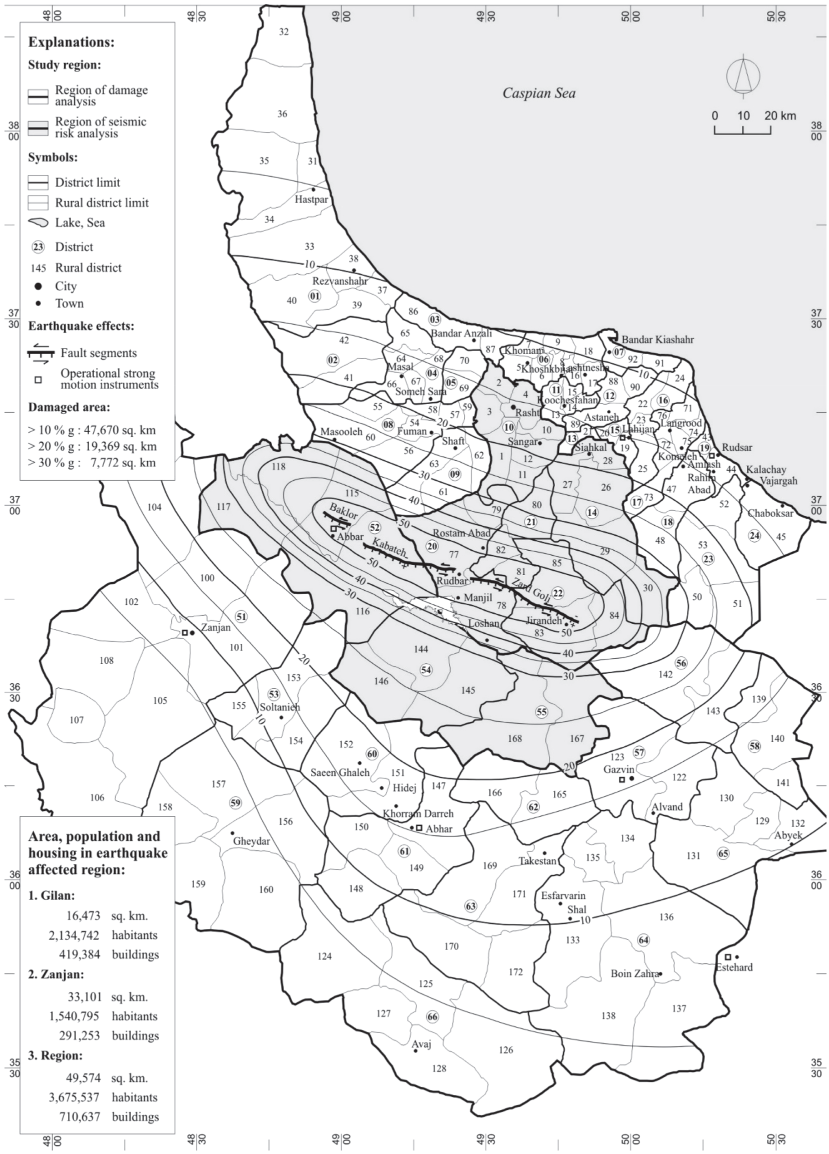

Figure 3. Peak ground acceleration distribution in the region due to June 20, 1990 Manjil Earthquake based on recorded surface ground motions, attenuation and damage distribution analysis. Recorded in Lahijan, PGA=0.176g on soft sandy soil deposit, at distance of 65km from the causative fault (after Petrovski, J. et all, 1998)

The earthquake hazard parameters estimated for each seismotectonic province of Iran are shown in the following table Table 1.4., (Tavakoli, B. and Ashtiany M., 1999).

Table 1. Source: Tavakoli, B. and Ashtiany M.G. "Seismic hazard assessment of Iran", 1999

Z	Span of Time	Beta	b	Beta	b	CC	Mmax	M	λ	N
		(KS)	(KS)	(GR)	(GR)			(obs)	(4.5)	
01	1926-95	1.55 ± 0.12	0.66 ± 0.05	1.54 ± 0.14	0.67 ± 0.06	0.96	8.1 ± 0.4	8.0	2.09	154
02	1963-95	1.19 ± 0.32	0.50 ± 0.13	1.17 ± 0.12	0.51 ± 0.05	0.97	7.2 ± 0.4	7.0	0.35	22
03	1960-90	1.30 ± 0.27	0.55 ± 0.11	1.13 ± 0.07	0.49 ± 0.03	0.99	7.2 ± 0.3	7.0	0.26	22
04	1941-90	1.17 ± 0.17	0.50 ± 0.07	0.93 ± 0.09	0.41 ± 0.04	0.96	7.6 ± 0.3	7.4	0.21	34
05	1927-95	1.27 ± 0.28	0.54 ± 0.12	1.27 ± 0.06	0.55 ± 0.03	0.99	7.4 ± 04	6.9	0.44	33
06	1929-95	1.39 ± 0.16	0.59 ± 0.07	1.34 ± 0.05	0.85 ± 0.02	0.99	7.6 ± 0.3	7.4	0.64	72
07	1923-95	1.95 ± 0.15	0.83 ± 0.06	1.71 ± 0.09	0.74 ± 0.04	0.99	7.5 ± 0.3	7.3	0.47	84
08	1924-95	1.99 ± 0.17	0.84 ± 0.07	1.34 ± 0.09	0.58 ± 0.04	0.98	7.4 ± 0.4	7.2	0.16	54
09	1922-95	1.94 ± 0.16	0.82 ± 0.07	1.40 ± 0.18	0.61 ± 0.08	0.97	7.3 ± 0.3	6.8	0.27	53
10	1932-95	1.47 ± 0.27	0.62 ± 0.11	2.38 ± 0.19	1.03 ± 0.08	0.98	6.6 ± 0.2	6.1	0.88	60
11	1944-95	2.24 ± 0.11	0.95 ± 0.05	1.59 ± 0.06	0.69 ± 0.03	0.99	7.6 ± 0.4	7.4	0.48	130
12	1920-95	2.12 ± 0.05	0.90 ± 0.02	1.98 ± 0.11	0.68 ± 0.05	0.99	7.2 ± 0.2	7.0	1.70	622
13	1925-95	2.49 ± 0.13	1.06 ± 0.05	1.86 ± 0.23	0.81 ± 0.10	0.98	7.0 ± 0.4	6.5	0.27	107
14	1928-95	1.98 ± 0.13	0.84 ± 0.05	1.71 ± 0.09	0.74 ± 0.04	0.99	7.6 ± 0.4	7.4	0.33	107
15	1927-95	1.41 ± 0.11	0.60 ± 0.04	1.19 ± 0.05	0.52 ± 0.02	0.99	7.9 ± 0.3	7.7	0.37	71
16	1900-92	1.68 ± 0.17	0.71 ± 0.07	1.83 ± 0.24	0.79 ± 0.10	0.96	7.6 ± 0.4	7.4	0.14	42
17	1907-92	1.72 ± 0.15	0.73 ± 0.06	1.68 ± 0.10	0.73 ± 0.04	0.98	7.5 ± 0.3	7.3	0.53	99
18	1924-92	1.61 ± 0.12	0.68 ± 0.05	1.62 ± 0.10	0.70 ± 0.04	0.99	7.9 ± 0.4	7.4	1.05	158
19	1900-95	1.68 ± 0.07	0.71 ± 0.03	1.48 ± 0.07	0.64 ± 0.03	0.99	7.9 ± 0.2	7.4	0.84	285
20	1929-95	2.32 ± 0.16	0.98 ± 0.07	1.69 ± 0.21	0.73 ± 0.09	0.95	7.5 ± 0.9	7.3	0.33	120

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