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DETERMINISTIC SEISMIC HAZARD EVALUATION FOR THE CITY OF DUZCE

Ahmet Hakan POLAT[1]

[1]Düzce Üniversitesi, Sanat, Tasarım ve Mimarlık Fakültesi, Mimarlık Bölümü, 81060, Düzce, Türkiye
e-mail: hakanpolat@duzce.edu.tr

Abstract-The main goal of the study is to define the design input motion scenarios for the future microzonation study. The study of the "Earthquake hazard Assessment in Duzce" is performed for the seismic hazard for the city of Duzce in order to get the design ground motion parameters for the next microzonation study. The main goal of the present study is to give briefly the steps and the uncertainties derived from the performing deterministic seismic hazard study for the city of Duzce based exclusively on the existing data and the seismicity of the region. This study uses all available sources of information, technical papers and research works performed so far. The seismotectonic environment of the area is very active, however there are certain uncertainties (to our knowledge) regarding the characteristic of the seismic source zones, the fault length, the magnitudes assigned to the faults, the seismicity parameters, the seismic history of the area, the attenuation relationships etc. During the few past years several research studies have contributed in better understanding the seismotectonic and geological background of the region. There are still a lot of parameters which are poorly known in order to provide more reliable seismological information of the area.Seismic hazard in Duzce was performed using uniform seismic zones (USZ). The seismic hazard was performed using a poisoning approach for mean return periods of 100 and 475 years. In the Seismotectonic zonation criteria; the seismic sources selected to perform a seismic hazard analysis were determined by Kayabali K (2002). In total 14 seismic sources were delineated in Turkey based mostly on Erdik et al (1985) and Yaltirak et al (1998) works. As a result, we have computed the PGA values and the acceleration response spectra for soft soil and rock (considered as outcrop) conditions in Duzce and for two mean return periods. In addition, several other comparisons with real records of previous earthquakes and seismic hazard studies will enhance the reliability of the obtained results. The design PGA value for rock (or outcrop) conditions and for 250 years return period is most probably between 0.3g and 0.35g. For 475 years return period it will be almost the double of it (we could accept in a reasonable way a PGA = 0.60g). These values will be further validated and then will be used, as incident peak ground accelerations, of a uniform incident ground motion, at the bedrock basement of Duzce for the detailed microzonation study of Duzce.

Keywords: Earthquake, Seismic, Analysis, Deterministic, Düzce.

1. INTRODUCTION

In the deterministic scenario concept; the seismic catalogue of historical earthquakes has certain uncertainties (the epicentres may differ more than 10km), as it is not always validated with good paleoseismic and other historical information. Consequently it has been decided to use as maximum credible earthquake the recent earthquake of Duzce in 1999 being aware that probably, during the last centuries, a stronger but less well documented earthquake might have occurred. The study of the "Earthquake hazard Assessment in Duzce" is performed for the seismic hazard for the city of Duzce in order to get the design ground motion parameters for the pilot microzonation study. The main goal of the present study is to give briefly the steps and the uncertainties derived from a deterministic seismic hazard study for the city of Duzce based exclusively on the existing data and the seismicity of the region. This study uses all available sources of information, technical papers and research works performed so far. There are still a lot of parameters which are poorly known in order to provide more reliable seismological information of the area. The seismic catalogue of historical earthquakes has certain uncertainties (the epicenters may differ more than 10km), as it is not always validated with good paleo seismic and other historical information. Consequently it has been decided to use as maximum credible earthquake the recent earthquake of Duzce in 1999 being aware that probably, during the last centuries, a stronger but less well documented earthquake might have occurred. Seismic hazard in Duzce was performed using uniform seismic zones (SSZ). The following assumptions were made;

- The selection of the zones and the seismicity parameters "a" and "b" for each zone that are affecting Duzce are based on previous seismological studies of Kayabali K, 2002.
- The standard deviation of the maximum magnitude for the earthquakes occurred between 1900- 2000 is 0.25. A threshold magnitude M=4.0 is selected.
- For the attenuation relationships, Ambraseys et al. (1996) relationship was assigned in order to perform a probabilistic study. Three other local attenuation relationships (Inan et al ,1996 ; Aydan et al, 1996; Ozbey, 2000) were used for the deterministic analysis in order to compare the results with the real records of Duzce earthquake
- Seismic zones were supposed to be plane, parallel to the surface.
- Focal depth was selected equal to 10km for the case of SSZ as the area is characterized by shallow seismicity.
- The grid used for the analysis for SSZ case is 1000*1000m and the dimensions of the grid for Duzce are 15X15km.

2. METHOD

A preliminary study is prepared using all available geotechnical and geophysical information. Thematic maps in GIS have been prepared and now we have a rather good picture of the geotechnical zonation for Duzce. One of the targets of this GIS geotechnical zonation with the existing data, is (a) to define the needs for supplementary geotechnical information, in the frame of the basic requirements of a pilot microzonation study, (b) to propose simplified soil zonation for the seismic hazard assessment (see below) and (c) to get an appropriate selection of adequate sites for the installation of the permanent Duzce's accelerometric network, foreseen in the present project and specific action. The simplified geotechnical zonation was made using Ambrasey's (1996) classification. According to Ambraseys (1996) the classes of site geology may be defined by the following ranges of average Vs velocities over the upper 30m of the site: Vs_{30}: Rock (R)>750m/sec, Stiff Soil (A) 360- 750m/sec, Soft Soil (S) 180- 360m/sec and very Soft Soil (L)< 180m/sec. As good quality records on very soft soil conditions are very restricted, soft&very soft soil categories are often grouped into one category called "Soft Soil". The compilation of all existing geotechnical and geophysical data (see the specific preliminary study) provided a rather good idea of the soil classification in Duzce in the upper 20-30m. Figure 12 present the simplified geotechnical map of the city according to the very simplified soil classification proposed by Ambraseys(1996). The central part of the city may be classified as "soft-locally very soft" soil, while the northern part as "stiff" soil.

3. FINDINGS

Duzce earthquake occurred on 12/11/1999 is selected as a representative earthquake (maximum credible) of an area. It is the more recent one, with well documented recordings of the strong ground motion in the center of the city and with a good description of the major damages in the city. Comparing the magnitudes and the epicentral distances of the more destructive earthquakes in the last century, Duzce (1999) earthquake is probably the most severe one. Reference earthquake is Duzce earthquake (11-12-1999): Epicenter (31.15E, 40.77N), shallow earthquake (depth: 10.0km), Ms= 7.2, R=8-10km. On November 12, 1999 at 6:57 PM (local time), a magnitude Mw 7.2 earthquake struck the Düzce-Bolu area of Turkey, 70 km east of Adapazari and 170 km northwest of Ankara. The earthquake epicenter is located near the town of Düzce, on the eastern end of the fault that is believed to have ruptured during the August 17, 1999, Mw = 7.4 event. The November 12, 1999 earthquake's epicenter is located at 40.77N 31.15E, which is about 110 km east of the magnitude 7.4 main shock on August 17 which killed over 17,000 people and injured another 50,000. On November 26, 1999, the preliminary estimates of casualties and injured were 755 and 4948, respectively. The material damage is extensive. 1342 structures have collapsed. A total of 7081 residential and industrial buildings are heavily damaged. Most of the damages are concentrated in Kaynasli a small town on the main highway between Duzce and Bolu. Loss of life in Duzce seems to be concentrated in few collapsed buildings that were "lightly" damaged in the August 17 earthquake, superficially repaired and later inhabited. Fire damage due to overturning of coal and wood burning stoves and explosion of bottled LNG. The main highway between Istanbul and Ankara passes close to the Duzce Fault while the whole area is mountainous and highly prone to landslide hazard. At Bakacak section (between Kaynaşlı and Bolu) of the main highway between Istanbul and Ankara two lanes of the four-lane highway collapsed due to land slide. Fortunately no vehicles were on the highway at the moment of the slide. The major viaducts in the regions are structurally intact except possible damaged to the bearings elements under the decks. The Bolu highway tunnel is under construction near the ruptured area. Table 1 summarizes the distribution of losses due to the November 12, 1999 earthquake in Duzce district.

Table1. Distribution of losses in Duzce caused by Duzce 1999 earthquake (Ansal et al ,1999)

<table>
<tr><th>Location</th><th>Number of Casualties</th><th>Number of Injured</th><th>Structures to be Torn Down</th><th>Heavy Structural Damage/ Residential</th><th>Heavy Structural Damage/ Industrial</th><th>Medium Structural Damage/ Residential</th></tr>
<tr><td rowspan="3">Duzce</td><td>344</td><td>2,800</td><td>617</td><td>3,588</td><td>874</td><td>152</td></tr>
<tr><td colspan="2">Medium Structural Damage/ Industrial</td><td colspan="2">Light Structural Damage/ Residential</td><td colspan="2">Light Structural Damage/ Industrial</td></tr>
<tr><td colspan="2">49</td><td colspan="2">174</td><td colspan="2">47</td></tr>
</table>

Figure 1. The location of epicenter of Duzce earthquake on Duzce fault (branch of NFA)- Ghasemi H. et al (2000).

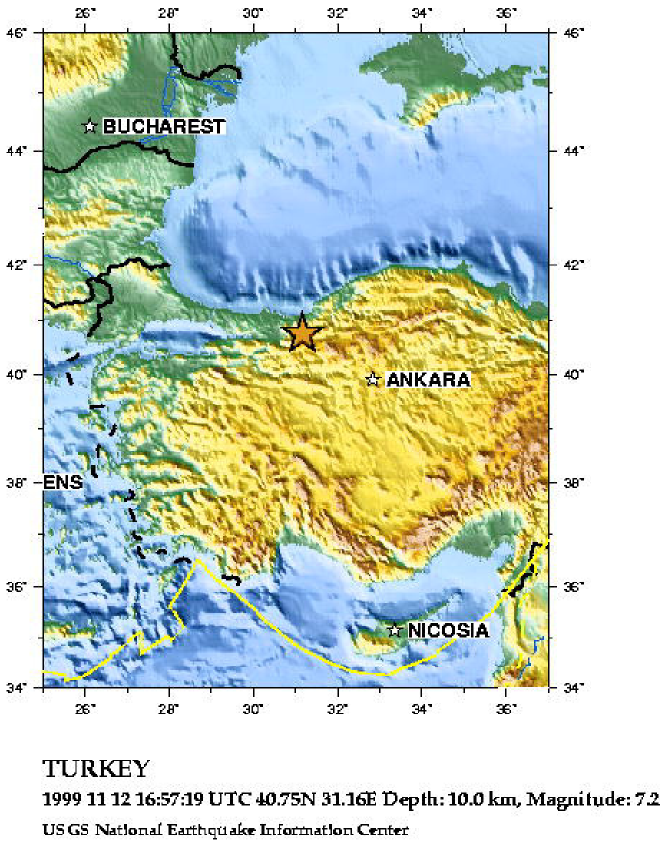

Figure 2. Location of the epicenter of Duzce earthquake

3.1. Attenuation of ground motions

Ambraseys 1996 attenuation relationship is selected in order to perform the earthquake hazard assessment (deterministic and probabilistic). A brief description is given below. AMB96 (Ambraseys et al., 1996) provides acceleration response spectral values. Ambraseys relationship is based on a good European, Turkish and Iranian earthquake database that includes MS ranging between 4.0 and 7.5. It introduces soils categories as well in a very simplified way (see above). The general form of the attenuation relationship is the following:

$$\text{Log}(y) = C1' + C2*M + C4*\log(r) + Ca*SA + Cs*Ss + \sigma*P \qquad (2)$$

Given that: $r = \sqrt{d^2 + h_0^2}$ (3)

The parameter y represents peak horizontal ground acceleration in g (related to structural period) while d is the shortest distance from the station to the surface projection of the fault rupture (in km). The parameter h_o is a constant and alternate according to structural period, as well as C_1', C_2, C_4, C_a, C_s(Table 2) for a given structural period). The standard deviation of log(y) is σ and the constant P takes a value of 0 for mean values and 1 for 84- percentile values of log(y). In our case/this study, we considered that P=0. The parameters S_a and S_s take the following values: Rock: Sa=0, Ss= 0, Stiff Soil: Sa= 1, Ss=0, Soft Soil: Sa= 0, Ss=1.

Table2. Constants given according to structural period (Ambrasey's 96)

T	C1'	C2	h0	C4	C_a	C_s	sigma	ln(10^sigma)
0	-1.48	0.266	3.5	-0.922	0.117	0.124	0.25	0.576
0.1	-0.84	0.219	4.5	-0.954	0.078	0.027	0.27	0.622
0.15	-0.98	0.247	4.7	-0.938	0.143	0.085	0.27	0.622
0.2	-1.21	0.284	4.2	-0.922	0.135	0.142	0.27	0.622
0.28	-1.46	0.326	4.4	-0.946	0.134	0.158	0.29	0.668
0.32	-1.63	0.349	4.2	-0.932	0.125	0.161	0.31	0.714
0.4	-1.94	0.377	3.6	-0.888	0.139	0.172	0.31	0.714
0.5	-2.25	0.42	3.3	-0.913	0.147	0.201	0.32	0.737
0.6	-2.49	0.438	2.5	-0.881	0.124	0.212	0.32	0.737
0.7	-2.67	0.463	3.1	-0.914	0.116	0.214	0.33	0.760
0.8	-2.86	0.485	3.7	-0.925	0.127	0.218	0.32	0.737
0.9	-3.03	0.502	4	-0.92	0.124	0.225	0.32	0.737
1	-3.17	0.508	4.3	-0.885	0.128	0.219	0.32	0.737
1.4	-3.52	0.522	3.4	-0.839	0.109	0.197	0.31	0.714
1.6	-3.68	0.52	2.5	-0.781	0.108	0.206	0.31	0.714

The Ambraseys' relationship is giving the peak horizontal ground acceleration (PGA) using a sample of 416 records for which site conditions have been classified.

$$\text{Log}(a) = -1.48 + 0.266*Ms - 0.922*\log(r) + 0.117Sa + 0.124Ss + 0.25P \qquad (4)$$

where: h_o= 3.5 and Sa, Ss, P are the same given in Ambraseys attenuation formerly described.

A comparison between the results applying Ambraseys' relationship and the three local attenuation relations for Turkey (i.e. Inan et al (1996), Aydan et al (1996) and Ozbey (2000)) is given for the Meteorological Station site in Duzce, where the recordings of the recent earthquake are available. Turkish attenuation relationships were given below (Table 3).

Table3. Turkish attenuation relationships

Relationship by	Empirical form
Inan et al (1996)	log PGA (gal) =0.65M-0.9log(r) -0.44
Aydan et al (1996)	PGA (gal)=2.8*($e^{0.9M}$ * $e^{-0.025r}$-1)
Ozbey (2000)	log PGA (grams)=-2.6517+0.4524Mw-0.986log(r^2+h^2)$^{0.5}$

Where:
M is the magnitude (=Ms when greater than 6.5; M_L otherwise)
Mw is the moment magnitude
r is the epicentral distance from fault (km)
h=7km

Ozbey (2000) relationship was developed using data from Kocaelli and Duzce earthquakes. The relationship is valid for strike-slip faulting, soft or stiff soil sites and for Mw between 4.0 and 7.4. (ref in Durukan E. 2002). Comparison of the results was given below (Table 4).

Table4. Comparison of the results PGA obtained by 4 attenuation relationships I Meteorological station in Duzce (R=10 km)

Location	Ambrasey's (1996)	Inan et al (1996)	Aydan et al (1996)	Ozbey (2000)
Meteorological station (31.17, 40.85)	0.44g	1.88g	1.33g	1.30g

As it can be noticed the differences are very large. The results obtained using Turkish attenuation relationships give much higher accelerations that the Ambraseys one, most probably due to the way that they are introducing near field conditions. The recorded PGA acceleration in the Meteorological Station is 0.55g which is quite close to the acceleration calculated by Ambraseys 96 relationship, while it is quite different from the results obtained by Aydan et al. Ozbey relationship is the same for soft and stiff soil sites as it depends only upon the magnitude and the distance and derived only from the data of Duzce and Kocaeli earthquake. This relationship hasn't been tested in other earthquakes in Turkey while Ambraseys 96 has been tested world-wide and it uses data from Turkey as well. For all these reasons we finally decided to select the Ambraseys 1996 relationship as more reliable to conduct this study.

4. CONCULUSION AND DISCUSSION

In this study, Duzce 1999 earthquake was selected as the appropriate deterministic scenario for Duzce. The results are compared with the results of Kayabali K et al, 2003 deterministic approach for Turkey. Although this comparison is quite indicative, it is very interesting to compare different methodologies. The main difference from the iso-acceleration map for all Turkey presented by Kayabali K et al (2003) is certainly due to the fact that it was derived using TUMDES code after the identification of all faults, calculation of the closest distance, assignment of a magnitude and providing an attenuation relationship to each fault. Moreover, as it wasn't possible to know the specific soil conditions of all Turkey, the attenuation relationship that it was assigned in each fault is, in our opinion, better corresponding to rock or stiff soil sites. Iso-acceleration map based on the relationship by Sadigh et al (1997) produced by Kayabali K et al (2003) were showed on Figure 3.

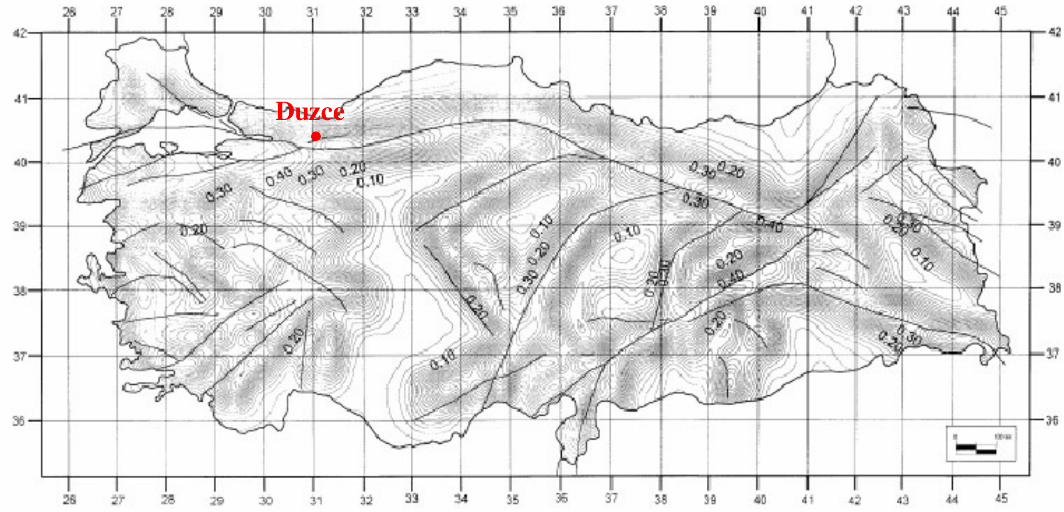

Figure3. Iso-acceleration map based on the relationship by Sadigh et al (1997) produced by Kayabali K et al (2003)

Considering all these issues the comparison is certainly rather acceptable especially for stiff soil conditions (Table 5).

Table5. Comparison of PGA between Kayabali K (2003) and this study

Duzce	Kayabali K et al (2003)	This study
PGA	Approximately 0.25g (rock-stiff soil)	0.44g (soft soil) For rock: 0.33g

Taking into account the various uncertainties, the different way of approaching deterministic scenario and the role of local soil conditions we may conclude that the differences are not very important. It seems that for rock (or stiff soil) conditions a PGA value roughly between 0.30g to 0.40g should be expected if we accept that the recent Duzce 1999 earthquake (Mw=7.1) may be considered as appropriate for the deterministic scenario.The reason of performing comparisons as those in Table 4 or Table 5 is mainly to check the results and hypothesis, with other results that are derived using different attenuation relationships or even different methodologies. In any case we should be aware that the uncertainties are very important.

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