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EARTHQUAKE INDUCED SOIL LIQUEFACTION INDEX OF DUZCE PROVINCE, IN TURKEY USING PROBABALILISTICAL AND STATISTICAL METHODS

Keywords: *liquefaction index, earthquake, probabilistic methods, Duzce (Turkey)*

A b s t r a c t

The 12 November 1999 Duzce earthquake (the erathquake had magnitudes M_W of 7.2) in Turkey caused a huge destruction and hazard for Duzce in Turkey sites in the Western Black Sea Region. In the study area, the main reason for destruction is observed due to liquefaction and its settlements sequencely. As known, liquefaction occurs in sandy soils and presence of the undeground water, in other words, soils in which the space between individual particles is entirely filled with water. In this research, probabilistic aproach was used to determine the liquefaction potentail index. For the study site, it was determined that the study area has very high seismic activity from the point of techtonic structure. Using probabilistic seismic risk analysis, the magnitude was estimated as 7.9. Utilizing this approach (Probabilistic), predicted magnitude and accelarations were calculated as 7.9 for magnitude and 0.42, 0.45, 0.55, 0.56, 0.72g for accelarations. In the first stage of the study, the dynamic stress ratio approach was exerted to the field data for SPT (N) to determine the liquefaction potential index and attained in Duzce region. Following this phase, the values of liquefaction potential indexes (LPI) were anticipated by this approach. Finally, the liquefaction maps were prepared according to the probabilistic earthquake approach.

Chapter 1

The city of Duzce is under the effect of seismic hazards because of its proximity to the North Anatolian Fault (NAF) and is the most active seismic zone in Turkey**.** The large earthquake of 12 November 1999 within the North Anatolian Fault zone caused widespread loss of life, damage to buildings, roads, and lifelines in the Duzce area. The facts mentioned above are reason enough to investigate liquefaction potential of sedimentary soils in the city of Duzce in order to indicate the zones of major risk due to this phenomenon. The neotechtonic framework of Turkey is outlined and charecterised by major intracontinental strike-slip faults, namely the dextral North Anatolian Fault zone and the sinistral East Anatolian Fault zone, between which the Anatolian block moves westward relative to the Eurasian plate in the North and the Arabian plate in the South owing to the continued convergence of these plates since the middle Miocene [1,2,3,4]. The city of Duzce is located in the North Anatolian Fault Zone that is seismically active. The study area has been seriously affected by the devastating Gerede (01.02.1944), Marmara (17.09.1999) and Duzce (12.11.1999) earthquakes. Bolu plain is a pull-apart type of basin [5]. An earthquake that may be occure in this area will affect the Duzce provision and cause to damage the buildings and individals, and cause to groud damage as liquefaction.

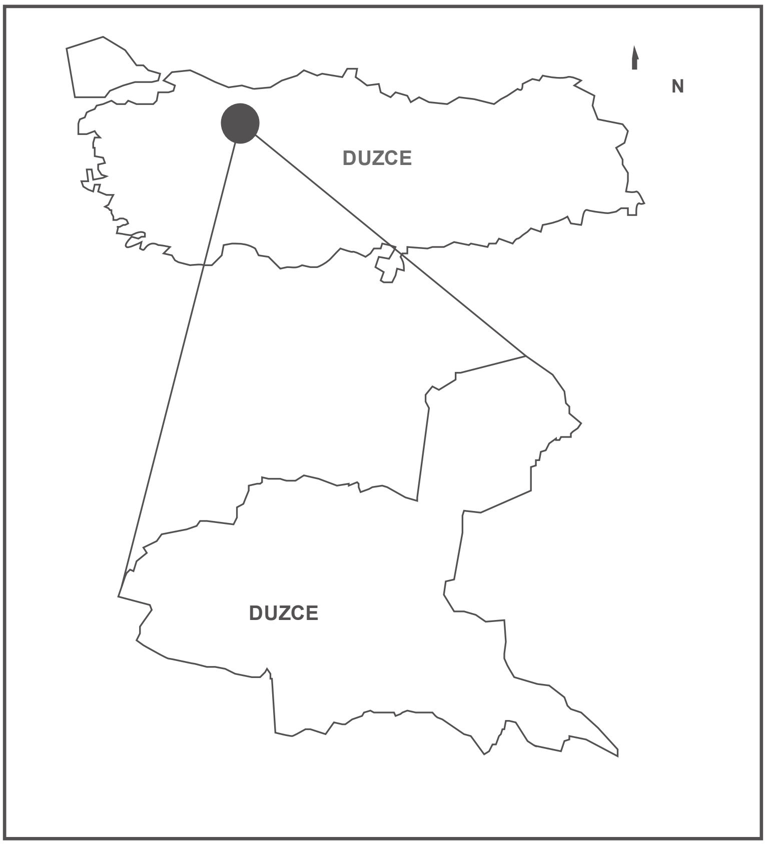
17 August Adapazarı Earthquake and 12 November 1999 (7.4 and 7.2) Duzce earthquakes caused great destruction and hazard for the Duzce sites. One of the main causes for the heavy damage to buildings is observed liquefaction induced settlements. Thus, assessment of soil liquefaction potential index is one of the most important subject of interest. The present simplified methods for evaluating soil liquefaction potential index utilize a deterministic safety factor to decide if liquefaction can occur or not. In recent years, engineers usually use the liquefaction potential index to assess the safetyness of a structure. Liquefaction resistance can be anticipated by in situ test and laboratory test. Standard Penetration Test (SPT), cone penetration (CPT) and Shear Wave velocity tests are the most used for the anticipation of liquefaction potentai index sensitivity [6]. These methods based on the SPT were improvised by Seed and Idriss [7]; Seed et al. [8]; Iwasaki et al. [9]; Tokimatsu and Yoshimi [10]; Youd and Idriss [11]. The methods by using the CPT include those developed by Seed and Alba [12]; Robertson and Compenella [13]. For engineering porposes, data obtained from site investigations including boring, laboratory tests are necessary to be used besides methods based on SPT and CPT [14; 15]. The liquefcation analysis is evaluated by Youd et al. [16]. Earthquake hazard analysis can be done in two ways deterministic seismic hazard analysis (DSHA) and the probabilistic earthquake hazard analysis (PSHA). In this paper, PSHA was used. The first step of the DSHA approach is the deter mination of the biggest earth quake that occurred in the past from the seismic sources in the study area. For this reason, there should be two things; (1) catholog shuld be available and if not or if there are some in sufficient information in the catholog then the value of biggest erathquake should be taken, (2) The second alternate is to choose the most suitable attenuation relationship which fits the charecteristics of the area. Here an effort has been made to determine the liquefaction potential index (LPI) from the factors of safety (FS) along the depth at each representative borehole at Duzce city in Turkey based on the method by Youd et al. [16].

The main purpose of this study is to research the variations of Liquefaction Potential Index depending on the probabilistic design earhquake parameter (Mw=7.9) obtained by probabilistic approach for soil liquefaction potential index for the city of Duzce (Turkey).

Chapter 2

Duzce city is situated in the North-Western Part of the Turkey and on the Motor way leading to Istanbul. It is under the effect of the North Anatolian Fault Zone (NAFZ) and is 30 km distant away from the Black Sea about 30 km. The city center is situated on the alluvial soil deposits (Fig. 1).

Fig. 1 The study area

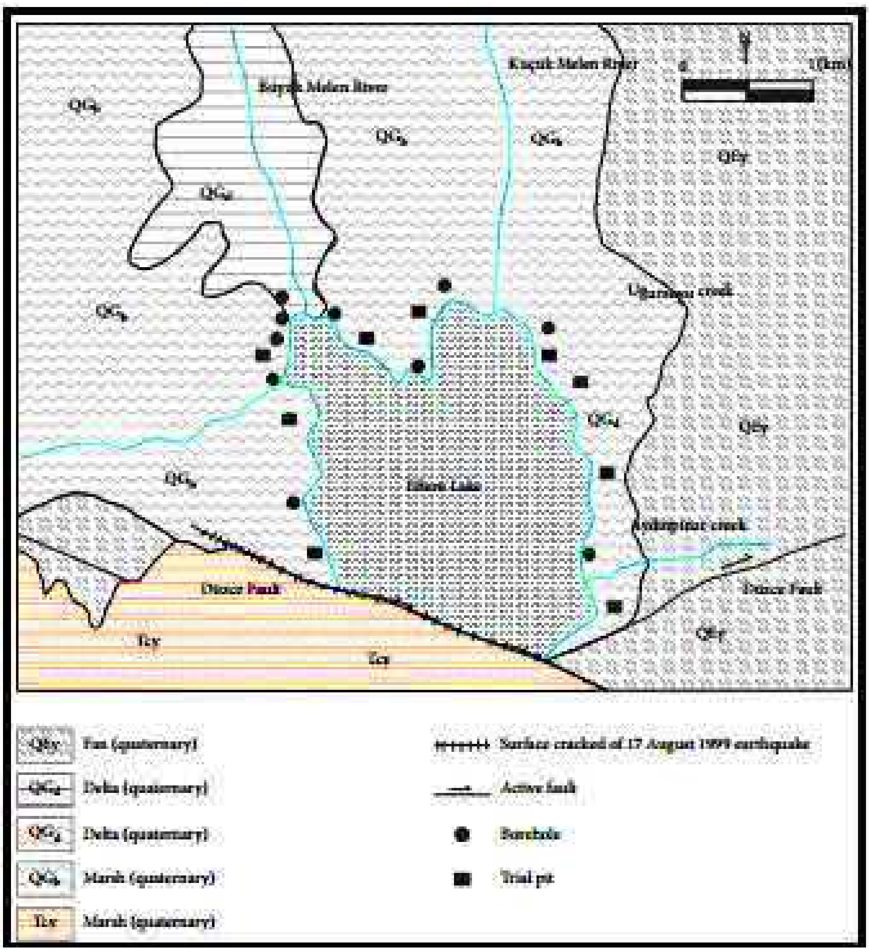


Chapter 3

Duzce plain is a pull apart type basin that is controlled by the lateral strike slip fault system in the NAFZ [6] (Fig. 2). Paleo and Neo-tectonic period of active faults exist at the north and south of the plain. There are several faults which are parallel and oblique to these major faults. During the 12 November, 1999, earthquake, the surface rupture ranged through Golyaka on the south towards to Kaynaşlı district on the east, ending in the Asarsu valley and the Bolu Tunnel. The city of Duzce is situated in the middle of the plain on a pressure ridge type hill and is probably tectonically controlled.

Historical earthquakes have been recorded on the Abant-Bayramoren segment in the south. There were 12 earthquakes between 1967 and 1890. The great earthquake of 17 August, 1668, (M_S =8) caused a disaster in Anatolia [17], with aftershocks continuing for 6 months [18]. The Bolu-Gerede earthquake (M_W=7.3) on January 2, 1944, was a major one, recorded after the implementation of instruments for scientific measurement of magnitude. It was noted that 2,381 people died and 50,000 houses were damaged [19]. Although the 17 August, 1999, Marmara and 12 November, 1999, Duzce earthquakes occurred on the western segment of the North Anatolian Fault, the measured average value of the horizontal ground acceleration was 0.52 g in Duzce [17].

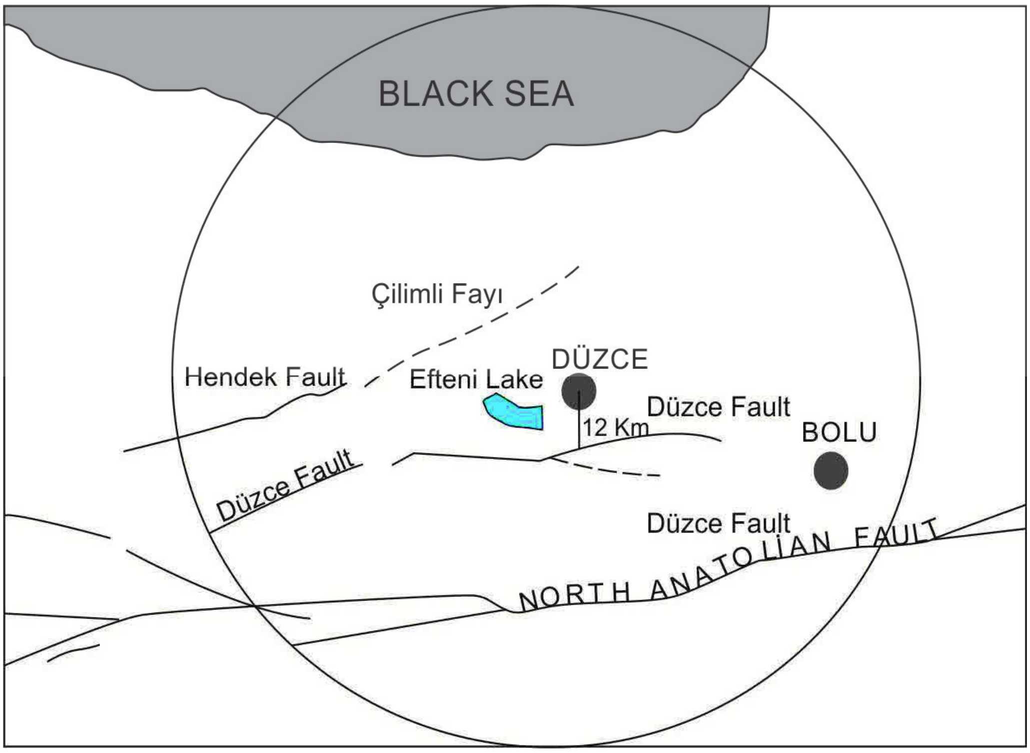
Fig. 2. Geological map of the study area and some borehole locations



Chapter 4

Potential earthquake source for study area was known as the segment which is entitled Duzce Fault, that is in the North Anatolian Fault (NAF) structure. This Fault Zone is situated at the distance of 13 km in the south of the study area, and has a length of 73 km (Fig.3). The Hendek Fault Zone is situated at the distance of 22 km in the north-west of the study area and mesured as 29 km (Fig. 4). The Çilimli Fault Zone is situated at the distance of 36 km in the north of the study area, and has a length of 22 km (Fig.3). The critical and effective fault zone with the highest possible acceleration in the study area is the Duzce Fault Zone placed on the branch of NAF. A circle of 100 km radius was drawn around the study area in order to identify the seismic design parameters and active seismic sources inside the circle throught to affect the study area and are vertically connected to calculate the shortest routes to the study area in km (Fig.4). These investigations and measurements show that there are three main fault zones which can be cracked inside the circle and the horizontal flying distances to the study area were measured as 13 km for Duzce Fault Zone, 22 km for Hendek Fault Zone and 36 km for Çilimli Fault Zone [20].

Fig. 3. Active seismic sources within the study area



The map of the Turkey live Fault published by Mineral Research and Exploration Institute indicates the total length of Duzce Fault, Hendek Fault and Çilimli Fault as 73 km, 29 km and 22 km respectively [20].

Chapter 5

The Republic of Turkey Prime Ministery Disaster and Emergency Management presidency (RTPMDEMP 2009a) earthquake database and International Seismological Center (2009) records were used for earthquake catalogs. The records of earthquakes that occurred between 1943 and 12 November 2014 were taken into condideration.

Here, Moment magnitude (Mw) used. The magnitude of the smallest earthquake that can cause seismic hazard is identified as 6.5 as according to moment magnitude. In general records, conversion to Mw scale of earthquake records which different institution proposed on different magnitude scales (body wave magnitude (Mb), duration magnitude (Md), surface wave magnitude (Ms), and local magnitude (MI) constitutes important problems.

Taking into account that different Centers use different measurement devices and different calculation methods, earthquake magnitudes also become different. Therefore, conversion of magnitude scales into each other can not be made with analytical methods. This situation needs the development of empirical equations. For thşs reason, standard least square method and orthogonal regression methods are the most commonly used empirical relationships. Standard least square method only considers the error that is caused by random earthquakes.However, Determination of earthquake m agnitu des d ep en ds on m any f actors. For this reason , it is not possible to determ ine magnitu des with out an error. In this case, using the orthogonal regression method is more appropriate w hich can also be used on the previous seismic hazard an alysis studies conducted in Turkey [21].

There are several There are several stochastic models which are considered dependent or independent to previousearthquakes on the estimation process of the earthquake occurrences. The Poisson model is the most widely used of these models. For earthquake events to build up a Poisson process, they must meet the following conditions first; earthquakes are independent in time, which means earthquake occurrences in any year does not affect re-occurrence. Earthquakes are independent in space. It means an earthquake which occurrs in any source area will not affect earthquake occurrence in another source area. There is zero possibility of being two separate earthquakes in the same place at the same time. According to Poisson model: the possibility of *n* number earthquake that is bigger than m_o lower magnitude limit in the studied area on *t* time period is given with the equation below (1):

$$(t) = e^{-\lambda t.\ (\lambda t)\ n} n! \quad (1)$$

In this equation, *Pn(t)* is the possibility of *n* number event during the *t* time, *n* is the number of events and λ is the number of earthquakes on unit time period (generally 1 year) in a studied area. In this study, Poisson model was used. To ensure the independent condition of this model, preliminary earthquakes and aftershocks were excluded from the analysis. Instrumental earthquake records in this region are given in Table 1.

Table 1. Magnitudes with ınstrumental records of earthquakes around the study area

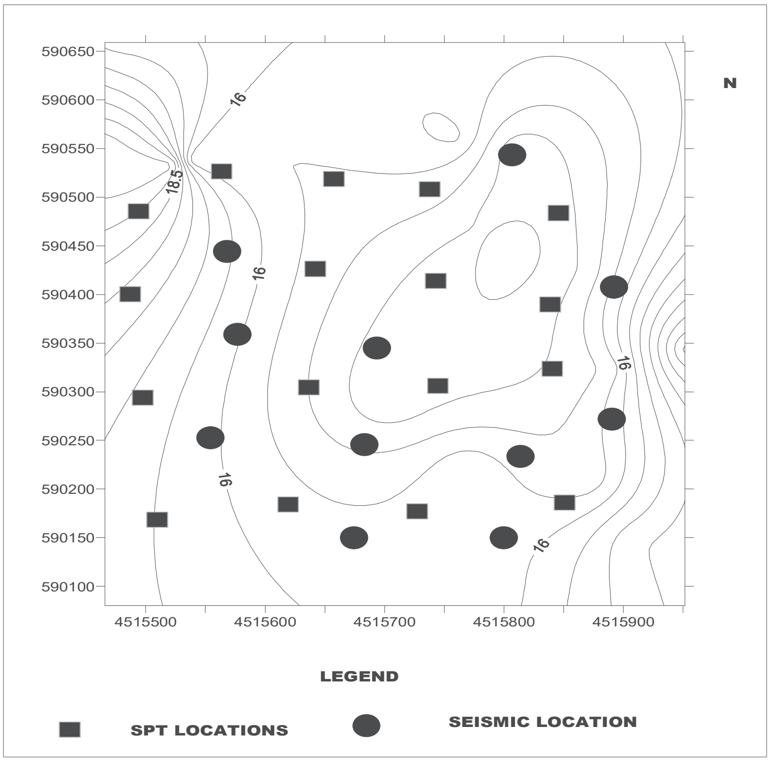
Date	Time	Latitude	Longitude	Depth	Md	Mp	Location
20.06.1943	15:32	40.85	30.51	10	Unknown	6.5	Duzce
26.05.1957	06:33	40.67	31	10	Unknown	7.1	Duzce
18.09.1963	16:58	40.77	29.12	40	Unknown	6.3	Duzce
22.07.1967	16:56:58.0	40.67	30.69	-	7.7	6	Duzce
17.08.1999	00:01:38.59	40.76	29.96	17	7.4	7.4	Duzce
12.11.1999	16:57:19.82	40.81	31.19	10.4	7.2	7.2	Duzce

Chapter 6

Geotechnical bore holes at 17 locations with depths ranging between 10.95-16.95 m (totally) 244.65 m have been drilled to determine the consistency of fine grained soils, stiffness of the coarse soils to have the undisturbed and disturbed samples (Fig.4). Standart penetration test–SPT has been carried out during the drillings and SPT N blow counts were obtained in the boreholes [22]. Then, representative soil samples have been obtained in order to determine the geomechanical properties of the soils. The 244.65 m thick alluvium is so heterogeneous including unconfined and confined aquifers. Groundwater level is mostly at the surface ranging between 1.4-4.5 m. Throughout the Duzce provision, different soil types are observed. The lowest SPT blow counts are observed in regions close to the Asarsu River flowing through the Efteni lake in the Duzce provision.

At the some places at the top layer with a depth of 5.0 m, the average value of SPT is 10-12, even at some places the values increases above 15. At the lower layers, the SPT counts obviously increase and the density of the distrubution of the formation at these levels can be cathogorized as dense to harder dense. In the study area in lower depths and especially along the Asarsu River, low SPT counts are observed. Where as the deeper levels, except in regions close to the Asarsu river towards to leading to Efteni lake, high SPT values are recorded. At the levels between 8-15 m, dense sand and sandy gravel are distingushed, however, sandy silt, clay, silt are observed. At lower levels the SPT blow counts are observed as 35-48. Finally, the SPT indicates the presence of some layers vulnerable to liquefaction in regions especially close to the Asarsu River.

Fig. 4. Borehole locations in the study area



Chapter 7

The liquefaction potential of a site depends on two factors: the nature of shaking and the liquefaction susceptibility of the sediments [23]. Thus, the first step for the assessment of potential is the evaluation of surface geology susceptibility to liquefaction based on published criteria such as the guidelines proposed by CDMG [24] and the criteria suggested by Youd [25]. In particular, a liquefiable area can be explained and delineated when reports of past liquefaction traces exist and the geological and geomorphological charecteristics are meeting the susceptibility criteria. In this study, the guidelines published by the California Department of Conservation, Division of Mines, and Geology [24] were applied to evaluate the liquefaction susceptibility of the sediments upon which the city of Duzce is situated. An area can be charecterized as liquefaction zone when meeting one or more of the following [24]:

- Evidence of historical liquefaction occurences,
- Data from in-situ test and analyses indicate that the soils are likely to liquefy,
- In case of lacking of the above data, a site is considered as susceptible to liquefaction when:area containing soils of late Holocene age, the groundwater is less than 13 meters deep and the peak ground accceleration (PGA) having a 10% probability of being exceeded in 50 years is greater than 0.1g,

- Soils of Holocene age where the depth of groundwater table is less than 10 meters and PGA (10% in 50 years) is greater than 0.2g,

Hence, the urban area of Duzce is meeting all the above criteria of CDMG [24] and consequently, is delineated as a susceptible to liquefaction zone.

Chapter 8

Earthquake relevant to hazard analysis is the calculation of likelihood of occurences in a specific time certain level of ground shaking induced by earthquakes. This kind of analysis is often defined a seismic hazard curve, that denotes the annual probability of exceedence versus ground motion amplitude. Regarding this subject, herein probabilistic seismic hazard approach was used to evaluate the seismic hazard of the North Anatolian Fault in North West Black Sea. The Duzce area is charecterized as a high seismicity region regarding the dynamic potential of Turkey. The designed peak ground acceleration (PGA) of the Turkish Seismic Code is equal to 0.24g, having a 10 % probability of being exceeded in 50 years (Turkish Seismic Code) while the maximum earthquake magnitude for the same recurrence interval is MW=7,2. Moreover, the average of the groundwater level is 1.4-4.5m depth according to data from boreholes that were performed to the urban area of Duzce.

The westward motion of the Turkey relative to Eurasia is related to the collision of between Arabia and Eurasia in the caucasus and Eastern Turkey, which is thought of region. Potential earthquake source area was started about 12 M years ago in the Mid-Miocene. The thickened crust in Eastern Turkey provides the gravitional potential energy, or buoyancy force, driving Turkey. Westwards; most of this motion being accomodated along the North and East Anatolian strike slips faults sytems [26; 1, 27; 28, 29; 30, 31; 32]. The neotectonic related geodynamic evaluation of the Mediterrenean started during and after the collision of Africa with Arabia. In Northern Anatolia, total consumption of the Tethian Ocean between the Sakarya continent Taurides created a compressional system which affects the region since late Cretaceous, [26; 27; 28, 29; 30, 31; 32].

The Eastern Anatolia tarnsferred to the N-S compression toward the west from Late Miocene onward. In this escape regime the North and East Anatolian strike-slip fault systems have played important roles. The N-S shortening deformation regime was replaced by an N-S extentional system in the western part of the Anatolian plate as a result of the escape tectonism. In this period, crust reached excessive degrees of thickening which was genereted from the upper mantle. The most frequent and destructive earthquakes occurred in Turkey, [6].

In the 20 th century the most devastating earthquakes were: the magnitude 8 Erzican-Refahiye earthquake of December 26, 1939; the magnitude 7.1 earthquake 13 on March 13, 1992 near

Erzincan which ruptured the same segment of the North Anatolian Fault that broke in 1939 (500 dead, 2,000 injured, 60,000 homeless); the Golcuk earthquake of 17 August 1999 with a Magnitude (Mw=7.4 that caused more than 15,000 dead and 40,000 injured people and economic losses of about 16 billion USD (7% of GDP), [6]. The combined toll of these earthquakes, concentrated on the North Anatolian Fault zone, is for the century 58.000 deaths, 116.000 injuries, and excessive building damages and monetary losses.

Regarding to Gutenberg and-Richter [33] recurrence relationships was given as (2);

$$\mathrm{Log\ (N)} = 2.55 - 0.58\ \mathrm{M} \tag{2}$$

Bisedes, eartquake occurence probability was given as (3) and in the Table 4.

$$\mathrm{Rm} = 1 - \mathrm{e}^{-(\mathrm{N})(\mathrm{M})(\mathrm{D})} \tag{3}$$

Where; Rm =Risk value (%); D,duration; N (M) for M magnitude (2) equation value.

Attenuation relationship was defined by two attenuation models. From a set of attenuation relationships, the design acceleration values of the city was calculated as 0.43 (for Joyner and Bore [34] model) and 0.47g (for Campbell[36] model with exceeding probability of 10% in 50 years (Table 4). Finally, a hazard curve for region was estimated (Fig. 5,6). Estimated acceleration values for 7.9 magnitude and several epicentral distances was given in Table 5-7.

Table 4. Earthquake occurence probability for region [6]

Ma gnitude	For D=10 (Years) Prob ability (%)	For D=50 (Years) Prob ability (%)	For D=75 (years) Prob ability (%)	For D=100 (Years) Probability (%)	Returni ng Period (Year) Q(M)= 1/n(M)
5	98.5	100	100	100	3
35.5	82	100	100	100	7
6	50.4	97	99.5	99.9	16
6.5	24.9	76.2	88.4	94.3	38
7	11.1	44.4	58.5	69	92
7.5	4.7	21.3	30.2	38.1	263

Table 5. Earthquakes in the study about 100 km radius [6]

Magnitudes	4.5≤ M≤5.0	5.0≤ M≤5.5	5.5≤ M≤6.0	6.0≤ M≤6.5	7.0 ≤M≤7.5
Numbers	54	15	9	2	1

Table 6. Earthquake Moment Magnitude obtained from probabilistic approach (obtained from Table 4) [6]

D (Year)	% Probability of Overturning	Moment Mahnitude
50	10	7.9

Table 7. Acceleration in the region according to probabilistic approach

Researcher	Moment Magnitude According to Probability Approach (Mw)	Acceleration(a) According to probability Approach (cm/sn2)
Gutenberg, 1956	7.9	0.42
Ambraseys,1995, Ansal, 1997	7.9	0.45
Inan vd. (1996)	7.9	0.56
Ulusay vd. (2004)	7.9	0.72
Joyner ve Bore (1981)	7.9	0.55

Fig. 5. Hazard curve for regıon by using Joyner and Boore [34] attenuation model

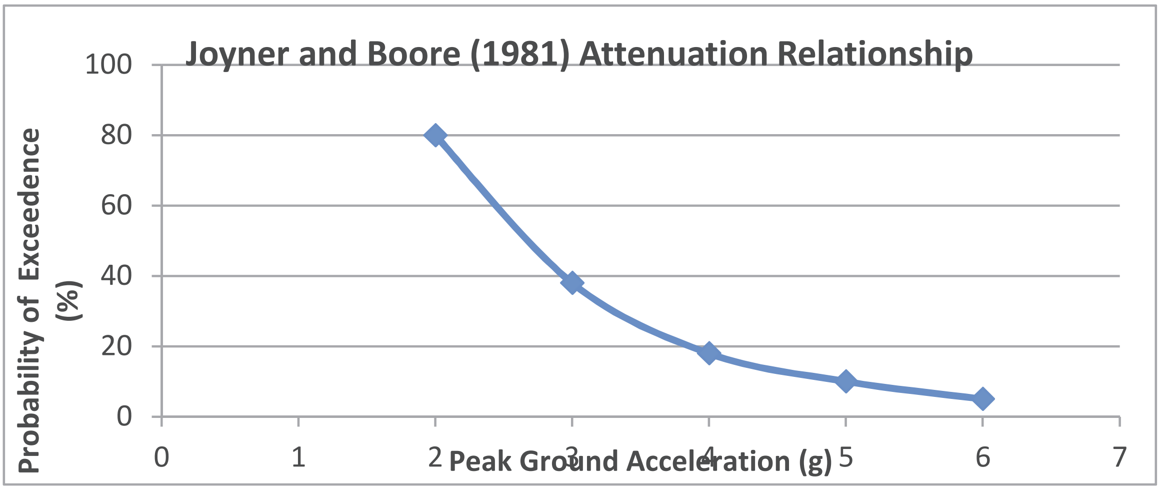
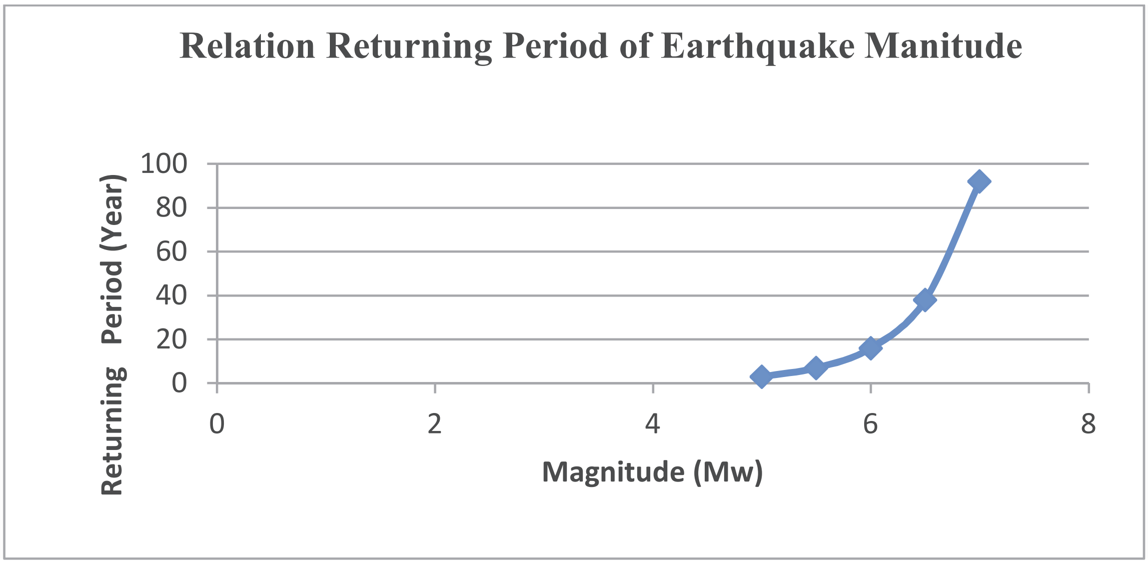


Fig. 6. Relation returning period of earthquake magnitude [6]



Chapter 9

In this study, a practical reliability-based method is developed for evaluation the soil liquefaction potential index of the Duzce (Turkey) Region. This study, based on conventional theory, enables the earthquake- induced cyclic stres ratio (CSR) and soil cyclic resistance ratio (CRR) and those were explained below.

The factor of safety against liquefaction (FS) is commonly used to quantify liquefaction potential. The factor of safety against liquefaction (FS) can be defined as follows (4).

$$FS = \frac{(CRR)_{M_W=7.5}}{(CSR)_{M_W=7.5,\sigma_V'}} MSF \tag{4}$$

Both CSR and CRR vary with depth, and therefore the liquefaction potential was evaluated at corresponding depths within the soil profile.

Criteria for evaluation liquefaction resistance based on SPT, CPT or shear wave data are largely embodied in the CRR versus N_1 60 plots [16]. This procedure is based on the relationship of SPT-N values, corrected for both effective overburden stress and energy, equipment and procedural factors effecting SPT testing (for N_1, 60- values) versus intensity of cyclic loading, expressed as magnitude–weighted equivalent uniform cyclic stress ratio (CSReq). The correlation between corrected N_1, 60- values and the intensity of cycling required to trigger liquefaction is also a function of fines content [8].

Chapter 10

The liquefaction potential index (LPI) quantifies the severity of liquefaction and predicts surface manifestations of liquefaction, liquefaction damage or failure potential of a liquefaction-prone area [36]. LPI is computed by taking the integration of one minus the liquefaction factors of safety along the entire depth of the soil column limited to the depths ranging from 0 to 20 m below the ground surface at a specific location. The level of liquefaction severity with respect to LPI as per Iwasaki et al. [9], Luna and Frost [36], and MERM [38] is given in Table 8. The factors of safety against liquefaction (FS) and the corresponding liquefaction potential index (LPI) were determined by comparing the seismic demand expressed in terms of the cyclic stress ratio (CSR) to the capacity of liquefaction resistance of the soil expressed in terms of the cyclic resistance ratio (CRR) [38].

Table 8. The level of liquefaction severity

LPI	**Iwasaki et al. [9]**	**Luna and Frost [36]**	**MERM [37]**
LPI=0	Very low	Little to none	None
0<LPI<5	Low	Minor	Low
5<LPI<15	High	Moderate	Medium
15<LPI	Very high	Major	High

In order to assess the liquefaction potential index at the city of Duzce, data from the geotechnical boreholes with SPT which were drilled for construction purposes by Duzce Municipality, were used. A total of 17 boreholes were taken into account in which the maximum and minimum depth of drilling were 15 and 7 meters, respectively. Afterwards, the factor of safety against liquefaction per layer, FS, was calculated as ratio of CRR (cyclic resistance ratio) to the CSR (cyclic stres ratio), based on the deterministic procedure,was known as the “simplified procedure” [7; 39; 16].

Youd et al [16] proposed the cyclic resstance ratio (CRR) using the following equatins (5).

$$\mathrm{CRR} = \frac{1}{34-\mathrm{N}_{1(60)}} + \frac{\mathrm{N}_{1(60)}}{135} + \frac{50}{\left(10\mathrm{x}\mathrm{N}_{1(60)}+45\right)^2} - \frac{1}{200} \qquad (5)$$

The normalized SPT-N value is influenced by the measured standard penetration resistance N, the overburden pressure factor Cn, the correction for borehole diameter, Cb the correction factor for rod length Cr and the correction for samplers with or without liners. The Cn was calculated according to the equation proposed by Liao &Whitman [40], while the borehole correction factors were estimated using the parameters suggested by Youd et al. [16]. Afterwards, a "fine content" correction was applied to the calculated N1(60) value in order to obtain an equivalent clean sand value N1(60)cs is given by the equations proposed by Youd et al. [16].

The CSR defines the seismic demand and is expressed as (6)

$$\mathrm{CSR} = 0.65 \frac{a_{max}}{g} \frac{\sigma_v}{\sigma_v'} r_d \tag{6}$$

Where σ vo: total vertical stress at depth z, σ vo′: effectictive vertical stress at the same depth, amax: peak hozintal ground acceleration, g:acceleration due to gravity and rd: stress reduction factor; estimated using the Liao &Whitman [40] equation.

In the end, the CSR values have been divided by the magnitude scalling factor, MSF, which is calculated using the equation proposed by Youd et al. [16].

In this study, the earthquake magnitudes was calculated according probabilistic approach, and amax that were employed for all the calculations including different equalities being valid for Turkey and in the world wide. The severity of liquefaction can be furthermore evaluated based on a weighting procedure proposed by Iwasaki et al. [9]. The authors proposed a procedure to evaluate liquefaction potential index (LPI), based on the in situ test data over the entire borehole (or more accurately, the top 20 m). The liquefaction potential index is defined as follows (7).

$$\mathrm{LPI} = \int_0^{20} F_{(Z)} W_{(Z)}\, d_Z \tag{7}$$

Where z is the below the ground surface in meters and is calculated as w(z)=10−0.5z; F(z) i a function of the factor of afety again t liquefaction, FS, where F(z)=1-FS when FS<1 and if FS>1 than F(z)=0. The depth of soil layers is limited to 20 m. Equation (15) gives the values of LPI ranging from 0 to 100.

Chapter 11

Varnes et al. [41] defined the natural disaster since the probability of occurence of a potentially damaging phenomenon within a given area and a specific period of time. The porpose of this study is the assessment of liquefaction risk and compilation of a map where the distrubution of liquefaction. In order to assess the liquefacton hazard at the Duzce city, the computed values of Liquefaction Potential Index (LPI) per site were employed according to Iwasaki et al. [9].

In this study liquefaction potential indexes are calculated and classified according to the probabilistic approach. The liquefaction maps for variations of liquefaction potential indexes depending on probabilistic design earthquake approach. The liquafaction maps obtained by probabilistic approaches for Duzce city were shown in figures 7-12 as below.

Fig.7. Variations of liquefaction index factors (LPI) depending on earthquake magnitude Mw=7.9 and acceleration a=0.42g

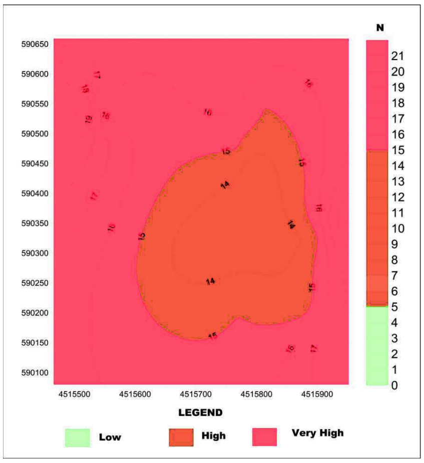


Fig.8. Variations of liquefaction index factors (LPI) depending on earthquake magnitude Mw=7.9 and acceleration a=0.42g

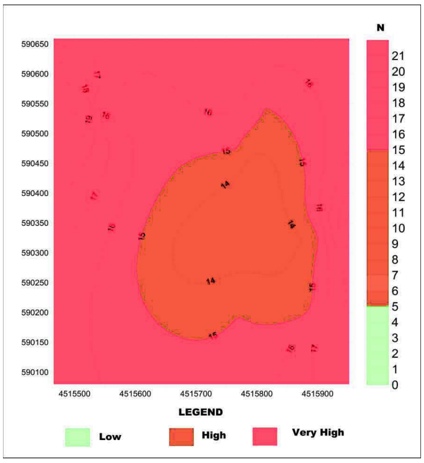


Fig.9. Variations of liquefaction index factors (LPI) depending on earthquake magnitude Mw=7.9 and acceleration a=0.45g

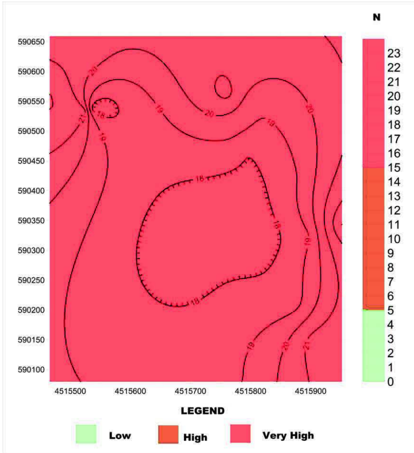


Fig.10. Variations of liquefaction index factors (LPI) depending on earthquake magnitude Mw=7.9 and acceleration a=0.55g

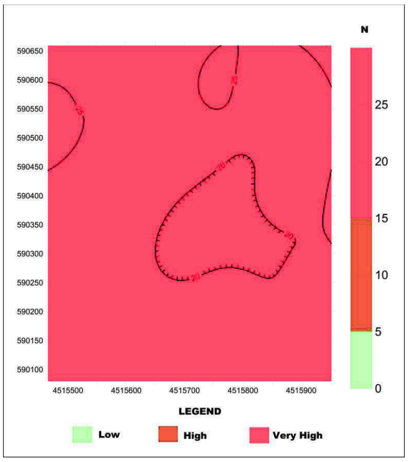


Fig.11. Variations of liquefaction index factors (LPI) depending on earthquake magnitude Mw=7.9 and acceleration a=0.56g

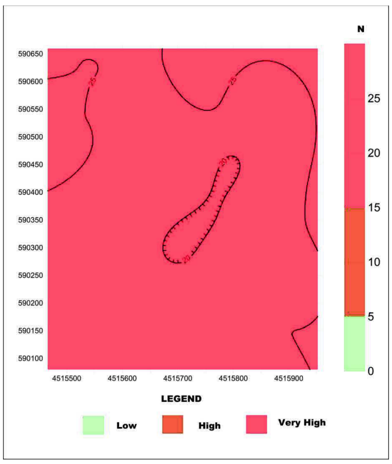
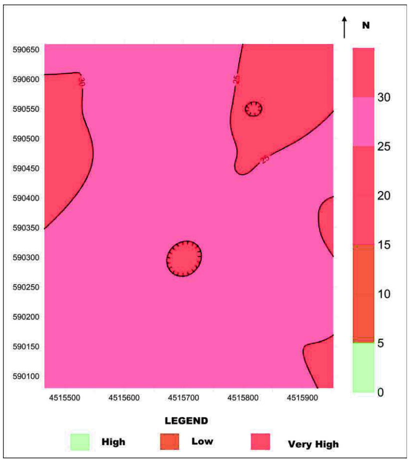


Fig.12. Variations of liquefaction index factors (PLI) depending on earthquake magnitude Mw=7.9 and acceleration a=0.72g



Chapter 12

The city of Duzce is located in the Western Part of Black Sea. This region is charecterized as high seismicity zone. The design accelerations were calculated by proababilistical approach having a 10% probability (pt) of being exceeded over a period (t) of 50 years. The purpose of this paper was the evaluation of liquefaction susceptibility of the sediments and the asessment of the liquefaction hazard at the urban area of Duzce (Turkey) according to the probabilistical approach.

Afterwards, the liquefaction potential was evaluated based on collected data from geotechnical profiles of borings with SPT while the liquefaction potential index per borehole was computed using the values of acceleration and moment magnitudes obtained from probabilistic approach. It was concluded that city of Duzce was assessed as likely to prone the liquefaction zone. Even more, the liquefcation surface evidences are more likely to occur for earthquake parameter according to the probabilistic approach. In the light of these experiences, it may be usufull for the city planner and engineers to construct special structures and to open the new residential ares.

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