Ali ATES[1]
Latif Onur UGUR[1]
Rifat AKBIYIKLI[1]
Hakan POLAT[2]
İnan KESKİN[3]
[1] Duzce University, Technolgy Faculty, Departmant of Civil Engineering, Turkey
[2] Düzce University, Faculty of Art, Design and Architecture, Departmant of Architecture, Turkey
[3] Karabuk University, Faculty of Engineering, Civil Enginneering Departmant, Turkey

SOIL LIQUEFACTION INDUCED SETTLEMENTS WITH INTERACTION OF EARTHQUAKE HAZARD ANALYSIS IN VICINITY DUZCE CITY (TURKEY)

Keywords: liquefaction index, earthquake, deterministic methods Duzce (Turkey)

A b s t r a c t

Duzce City (Turkey) is in a tectonically active location that is particularly affected by the northern branch of the North Anatolian Fault Zone. The 12 November 1999 Duzce earthquake (the earthquake had magnitudes MW of 7.2) in Turkey caused a huge destruction and hazard for Duzce in Turkey sites in the Western Black Sea Region. Magnitudes 7.2 and 6.9 earthquakes in 1999 caused great destruction in Duzce. In study area, The heavy damage to buildings and other civil engineering structures was mainly due to liquefaction-induced settlement and site effects such as amplification. In the structure of the this research, probabilistic and deterministic aproaches were used to determine the liquefaction induced settlement for several earthquake parameters. Utilizing by deterministic seismic risk analysis, the magnitudes were estimated for the two different rupture (with two different fault lengths, 74, 36 km) model of North Anatolian Fault Zone in the Western Black Sea Region. Utilizing the approaches (deterministic and Probabilistic), predicted magnitudes and accelarations of earthquakes were taken into account as alternatively 6.9, 7.2, 7.9 for magnitudes and 0.27, 0.35, 0.4, 0.42, 0.45, 0.46, 0.55, 0.56, 0.72g for accelarations. For several design earthquakes, in the first stage of the study of liquefaction, the dynamic stress ratio approach was exerted to the field data for SPT (N) to determine the soil liquefaction induced settlements and attained in Duzce region. Following this phase, the values of liquefaction induced settlements were anticipated with this approach. In the first phase of this study, the soil liquefaction potential index (LPI) and the liquefaction induced soil settlement were estimated due to probabilistic and determinitic aproaches. Finally, the maps liquefaction induced settlements were obtained and drawn.

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 [McKenzie,b1971;Dewey and Şengör, 1979; Şengör, 1980; Barka and Gülen, 1988;Koçyiğit, 1989]. 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 [Gokten et al.,1998].

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 [Özçep and Zarif, 2009]. These methods based on the SPT were improvised by Seed and Idriss [1971]; Seed et al. [2001]; Iwasaki et al. [1992]; Tokimatsu and Yoshimi [1983]; Youd and Idriss [1997].

Soil site conditions, as has been reported in many studies play an important role as one of the triggers of earthquake damage. The determination of site conditions required, identification of the soil stratification and properties of soil layers based on detailed geotechnical and geophsical tests [Borcherdt and Gibbs 1976, Iglesias 1988, Lekkas 1996, Seed et al., 2001, Özel et al., 2002].

Soil liquefaction resistance is estimated by in situ test or laboratory tests. Standard penetration, cone penetration and shear wave tests are the most used for the estimation of liquefaction susceptibility. Methods based on the SPT (standard penetration test) were developed by Seed and Idriss [1971], Seed et al. [2001], Tokimatsu and Yoshimi [1983] and Youd and Idriss [1997]. Regarding with liquefaction methods on using the CPT (conic penetration test) developed by Seed and Alba [1986], and the methods by using the shear waves developed by Stokoe et al. [1988], Andrus and Stokoe [1996, 1997, 1999] and Dobry et al. [1981]. The state of art of liquefaction analysis is evaluated by Youd et al. (2001). The phase of the liquefaction induced settlement analysis and total soil settlements were estimated by using Isihara and Yoshimine [1992].

In recent years, geological and civil (geotechnical earthquake) engineers in most countries are involving with the investigations of more earthquake hazard problems regarding with soils than evere before. These kinds of problems are crucial for people and the economical developments of the countries. For this important position to be conceived, a wide and huge effort should be considered to analysis the soil earthquake soil structure interaction problems.

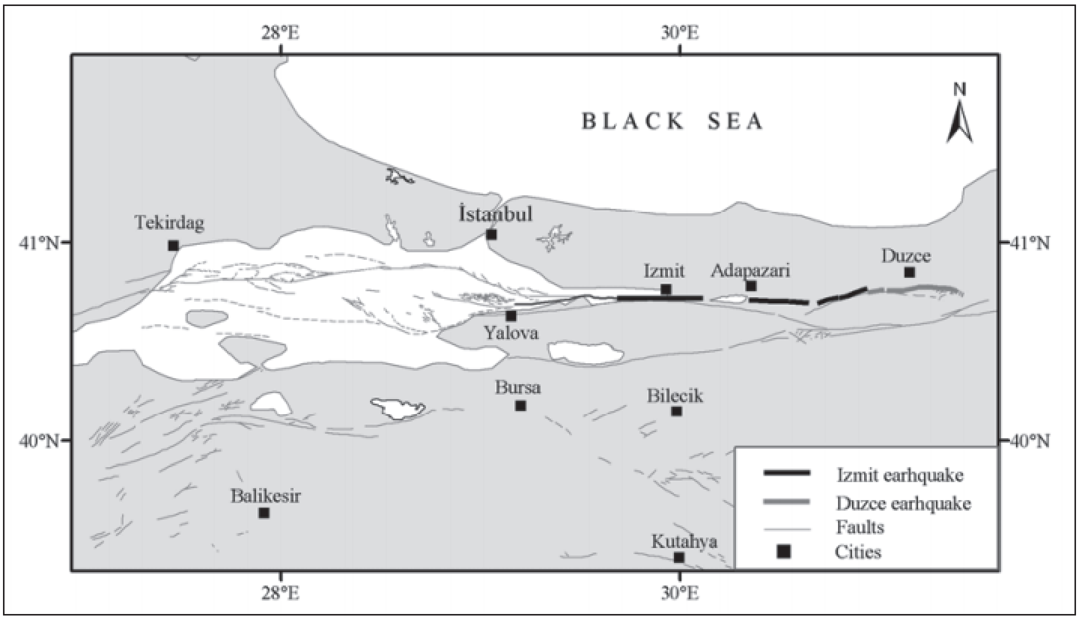
The state of art of liquefcation analysis is evaluated by Youd et al. [2001]. In this paper, an attemp has been made to determine the liquefaction potential index (LPI) and liquefaction induced settlements from the factors of safety (FS) along the depth at each representative borehole at Duzce city in Turkey based on the method by Youd et al. [2001].

Main goal of this work is to estimate the liquefaction induced settlements by empirical methods with field geotechnical data for assessing ground damage triggered by liquefaction induced settlements or soil amplifications around buildings in the vicinity of Duzce City depending on the several design earhquake parameters obtained by deeterministic and probabilistic approach 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 (Fig.1). It is under the effect of the North Anatolian Fault Zone (NAFZ) and is distance 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 [http:www.koeri.boun.edu.tr./earthqk/earthqk.html]



Chapter 2

Duzce plain is a pull apart type basin that is controlled by the lateral strike slip fault system in the NAFZ [Gökten et al.,1998] (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. Major earthquake records in this region are given in Table 1. 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 [Demirtaş, 2000], with aftershocks continuing for 6 months [Ambraseys, 1998]. 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 [Tasman, 1944]. 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 0.54 g in Duzce [Demirtaş, 2000].

Fig. 2. Destructive earthquakes along the North Anatolian fault in this century[Ulutas and Ozer, 2010]

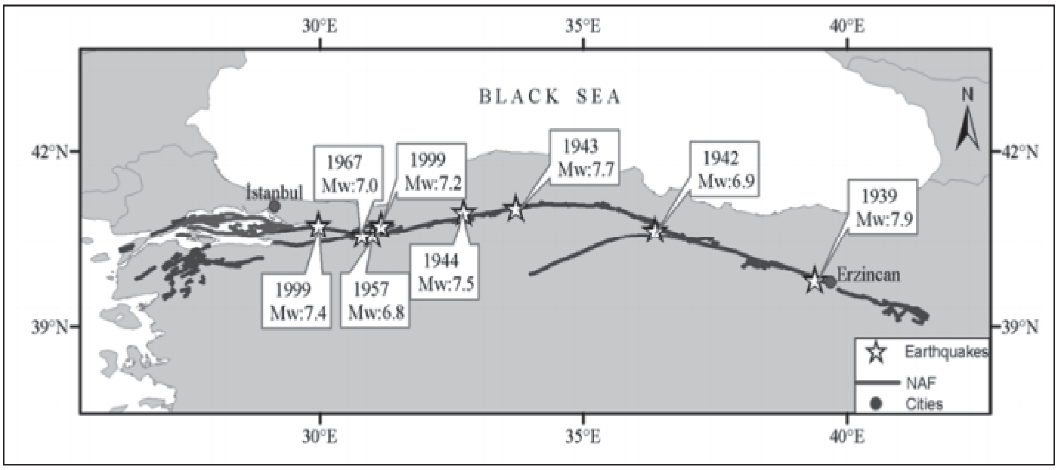


Table 1. Magnitude and damage records of earthquakes around the study area [NECM, 2014]

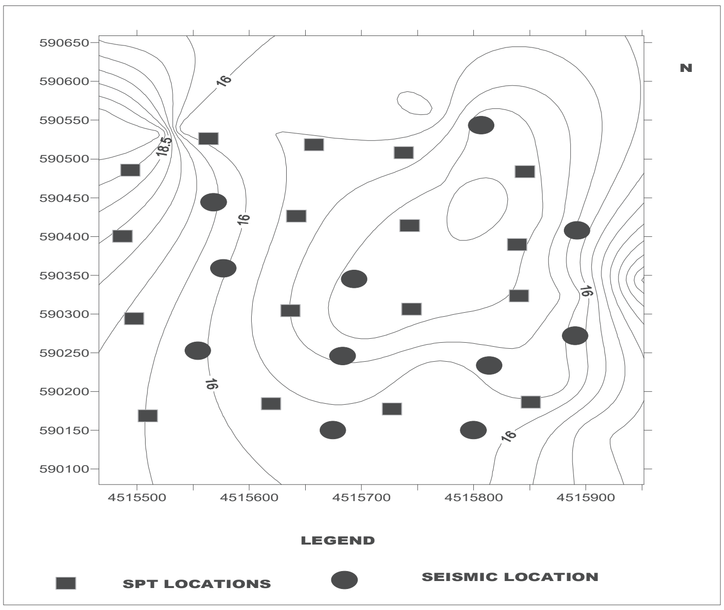
Locations	Date	Epicenter	M_W	Total damage	Death Injury on structures
Murefte	09.08.1912	40.60-27.20	7.3	5.540	216466
Hendek	20.06.1943	40.85-30.51	6.6	No	336No
Gerede	01.02.1944	41.41-32.69	7.2	20.865	3.959 No
Duzce	10.02.1944	41.00-32.30	5.4	900	No No
Mudurnu	05.04.1944	40.84-31.12	5.6	900	30 No
Yenice	18.03.1953	39.99-27.36	7.4	9.670	265 336
Abant	26.05.1957	40.60-31.20	7.1	4.201	52 100
Çınarcık	18.09.1963	40.77-29.12	6.3	230	126
Adapazarı	22.07.1967	40.60-30.89	7.2	5.569	89 235
Gelibolu	27.03.1975	40.45-26.12	6.4	980	7No
Golcuk	13.09.1999	40.80-30.03	5.7	No	No unknown
Duzce	12.11.1999	40.79-31.21	7.2	15.389	845 4.948
Bolu	17.11.1999	40.83-31.51	5.0	No	No No
Bolu	22.03.2000	40.94-31.58	5.4	No	No No
Yigilca	26.08.2001	40.93-31.53	5.1	No	No No

Chapter 3

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.3). Standart penetration test–SPT [ASTM] D 1586-99 has been carried out during the drillings and SPT N blow counts were obtained in the boreholes. 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. 3. Borehole locations in the study area



Chapter 4

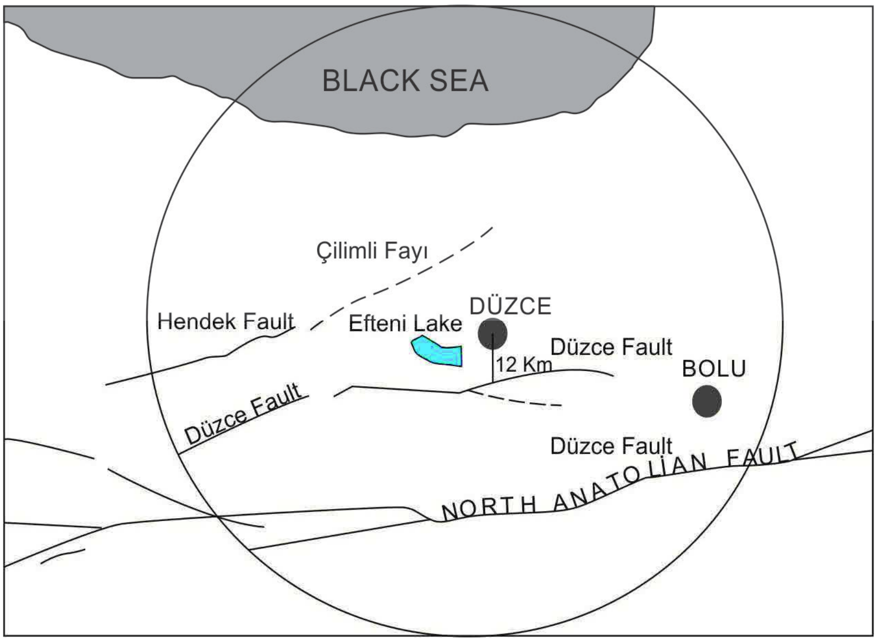
Earthquake relevant to hazard analysis is the calculation of likelihood of occurences in a specific time certain level of ground shaking induced by earthquakes. This kind of analysis is often defined a seismic hazard curve, that denotes the annual probability of exceedence versus ground motion amplitude. Regarding this subject, there are two approaches; deterministic and probabilistic seismic hazard approaches were used to evaluate the seismic hazard of the North

Anatolian Fault in North West Black Sea. The Marmara Sea is an intra-continanential marine basin between the Aegean and Black Sea. It is in a tectonically very active region located on the North Anatolian Fault (NAF) zone (Şengör, 1979; Barka, 1992; Straub et al., 1997; Le Pichon et al., 2001; Şengör et al., 2004). The NAF is a major transform-plate boundary that has produced devastating historical earthquakes along its 1600 km length (Ambraseys and Finkel, 1995; Soysal et al., 1981). The Duzce basin was considered as potential earthquake area on the North Anatolian Fault.

Chapter 5

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.4). 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.4). 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).

Fig. 4. Identification of seismic sources within 100 km radius to the study area



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 [Şaroglu et al.,1992].

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 [Şaroglu et al.,1992]. Regarding to next earthquake to be occurred, Duzce Fault Zone which is the shortest distance to the study area and has potential to produce earthquake was taken into consideration in this study. Required input for hazard analysis is a presence of active faults in the region. For the West Black Sea region, It was assumed two models (A, and B) for sesmic hazard for being likelihood of earthquake; Model A: approximately 75 km rupture length; Model B: approximately 37.5 km ruprure lenth. The magnitudes relating with these models were assumed in (Table 2a, 2b). It is proposed by Mark [1977]'s approach that ½ and 1/3 of this fault zone could be ruptured. Accordingly, the moment size of probable seismic design was calculated by using the equation of authors indicated in Table 2b. Peak ground accelerations were calculated using the equations in Table 3a,3b.

Table 2a.Eqations for rupture length and magnitude forecastings

Researcher	**M (magnitude)**	**Magnitude Type**	**Equations Number**
Ambraseys and Zatopck (1968)	M=(0.881LOG(L)+5.62)	M_S	(1)
Douglas and Ryall (1975)	M=(LOG (L)+4.673)/0.9	M_S	(2)
Patwardan et al., (1980)	M=(LOG (L)1.1+5.13	M_S	(3)
Wells and Coppersmith (1994)	M=5.16+(1.12LOG (L))	M_W	(4)

Table 2b. Model A:approximately 75 km rupture length; Model B:approximately 37.5 km rupture length: Magnitude calculations for these models

Researcher	**M (magnitude) Ranges for Model A (L=75)**	**M (magnitude) Ranges for Model B (L/2=37.5)**
Ambraseys and Zatopck (1968)	7.2	6.9
Douglas and Ryall (1975)	7.2	6.9
Patwardan et al., (1980)	7.2	6.9
Wells and Coppersmith (1994)	7.2	6.9

Table 3a. PGA equations used in the region according to deterministic approach

Researcher	Acceleration(a) cm/sn2 (L)	Equations Number
Gutenberg, 1956	Log a=-2.1+0.81M-0.027M2	(5)
Ambraseys,1995, Ansal, 1997	Log a=0.329M-0.00327R-0.792LogR+1.177	(6)
Inan vd. (1996)	Log PGA=0.65M-0.9logRe-0.44	(7)
Ulusay vd. (2004)	PGA=2.18e0.0218(33.3MW-Re+7.8427SA+18.9282SB)	(8)
Joyner and Boore (1981)	Log (Ap)=-1.02+0.249*Mw-log r-0.00255*r	(9)

Table 3b. Peak ground accelerations calculated according to the deterministic approach

Researcher	Acceleration(a) cm/sn2 (L)	Acceleration(a) cm/sn2 (L/2)
Gutenberg, 1956	0.37	0.35
Ambraseys,1995, Ansal, 1997	0.4	0.4
Inan vd. (1996)	0.5	0.46
Ulusay vd. (2004)	0.45	0.4
Joyner and Boore (1981)	0.33	0.27

Chapter 6

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 ration (CRR).

- *Determination of Factor of Safety*

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 (1).

$$FS = \frac{(CRR)_{M_W=7.5}}{(CSR)_{M_W=7.5,\sigma'_V}} MSF \quad (1)$$

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 [Youd et al., 2001]. 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 [Seed et al., 2001].

- 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 [Luna and Frost, 1998]. 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. [1982], Luna and Frost [1998], and MERM [2003] 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) [Dixit et al., 2012] (Table 4).

Table 4. The level of liquefaction severity

LPI	Iwasaki et al. (1982)	Luna and Frost (1998)	MERM (2003)
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” [Seed and Idriss, 1971; Seed et al., 1985; Youd et al., 2001].
- Youd et al [2001] proposed the cyclic resstance ratio (CRR) using the following equatins (2).

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

- 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 [1986], while the borehole correction factors were estimated using the parameters suggested by Youd et al. [2001]. 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. [2001].

The CSR defines the seismic demand and is expressed as (3)

$$CSR = 0.65\frac{a_{max}}{g}\frac{\sigma_V}{\sigma_V'}r_d \quad (3)$$

Where σ_{vo}: total vertical stress at depth z, $\sigma_{vo'}$: effectictive vertical stress at the same depth, a_{max}: peak hozintal ground acceleration, g:acceleration due to gravity and r_d: stress reduction factor; estimated using the Liao &Whitman [1986] 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. [2001].

In this study, the magnitudes were equally calculated for different length of faults according to be likely cracked occurring possible earthquake, and a_{max} 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. [1982]. 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 (4).

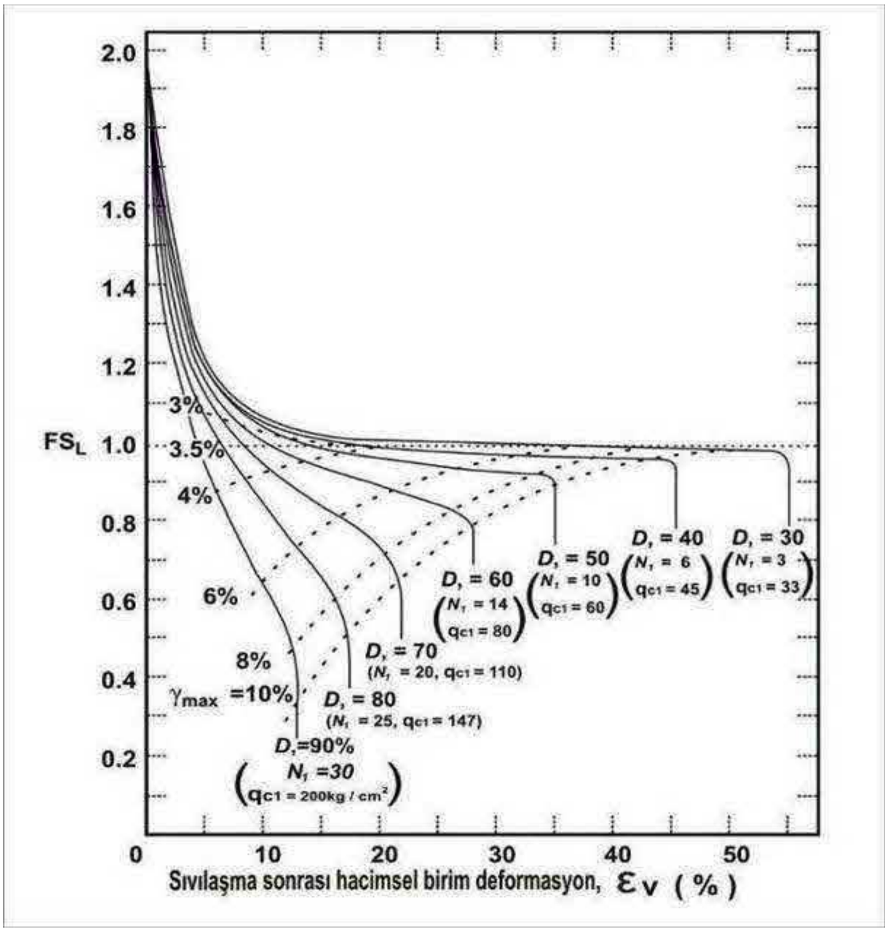
$$LPI = \int_0^{20} F_{(Z)} W_{(Z)}\, d_Z \qquad (4)$$

Where z is the below the ground surface in meters and is calculated as w(z)=10−0.5z; F(z) is a function of the factor of safety against 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 (5) gives the values of LPI ranging from 0 to 100.

- *Liquefaction induced settlements according to Ishihara and Yoshimine (1992) Method*

The liquefaction induced settlement can be calculated the unit volume change by using the safety factor, which is calculated with the help of any liquefaction analysis method proposed by Ishihara ve Yoshimine [1992] (Fig. 5).

Fig. 5. The relation between volume change after liquefaction and safety factor[Ishihara and Yoshimine, 1992]



The amount of settlings in a depth can be calculated by multiplying the unit volume changes, that are calculated by Ishihara and Yoshimine method, and the soil layers' thickness includes the unit volume changes.(Eş. 5). If it is started to add the settlings from the base of the soil layer, it is also gotten the total settling values that will form on the surface of teh soil. (5).

$$S=\frac{\varepsilon_h}{100}\Delta z \tag{5}$$

Here ; $\varepsilon_{h,}$ is the unit volumemetric strain in the layer, Δz, is the thickness of soil layer (6).

$$S_{top} = \sum_{i} S \tag{6}$$

Here; S, is the amount of settlements, $S_{top,}$ is the total amount of settlements on the soil surface.

After the analysing of the data, taken from the study area, it will be found the amount of the settlments by using the Liquefaction Potential Indexes factor, according to Ishihara andYoshimine's method [1992].

The porpose of this study is the assessment of liquefaction risk and compilation of a map where the distrubution of liquefaction induced ground settlement. 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. [1982].

In this study liquefaction potential indexes are calculated and classified according to deterministic approaches. Following this phase, the liquefaction induced settlement maps for variations of liquefaction potential indexes depending on several design earthquakes were obtained and given in Figures 6-13 as below.

Fig.6 Liquefaction induced settlement maps depending on earthquake magnitude Mw=6.9 and acceleration a=0.33

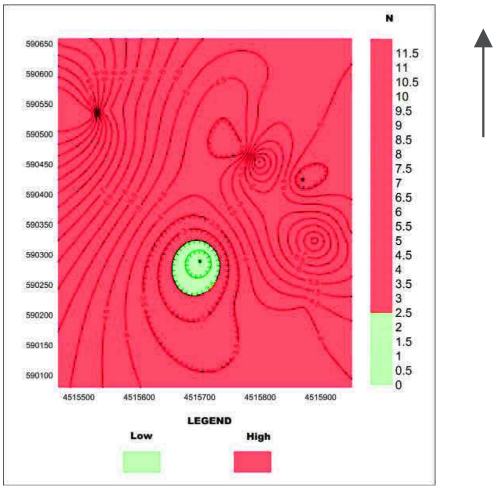


Fig.7. Liquefaction induced settlement maps depending on earthquake magnitude Mw=6.9 and acceleration a=0.45

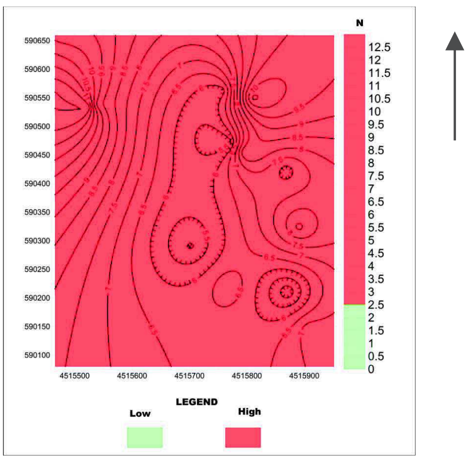


Fig.8. Liquefaction induced settlement maps depending on earthquake magnitude Mw=6.9 and acceleration a=0.5

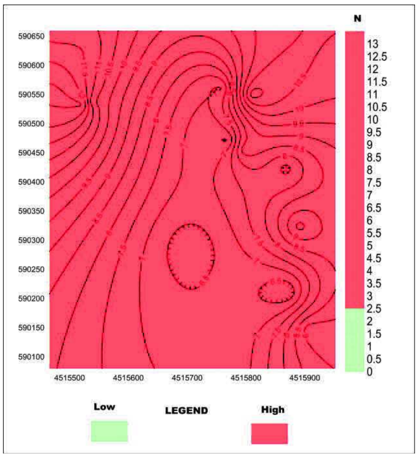


Fig.9. Liquefaction induced settlements map depending on earthquake magnitude Mw=7.2 and acceleration a=0.33

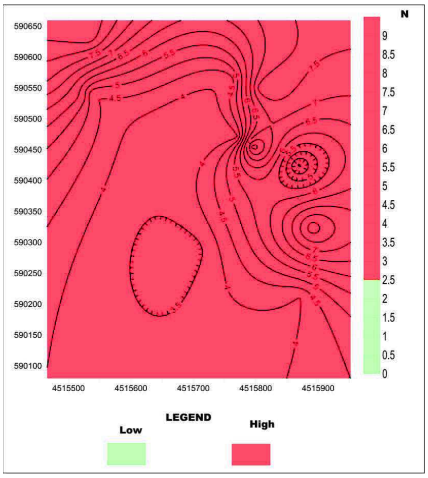


Fig.10. Liquefaction induced settlements map depending on earthquake magnitude Mw=7.2 and acceleration a=0.37

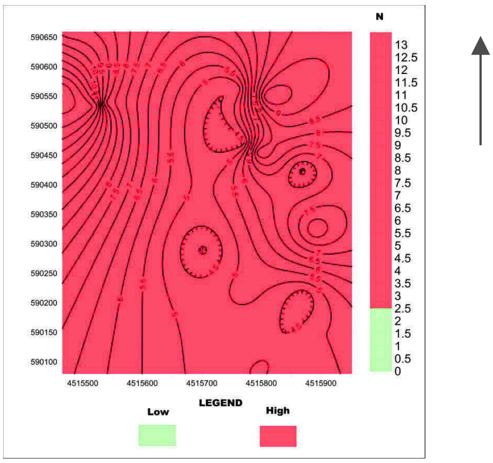


Fig.11. Liquefaction induced settlements map depending on earthquake magnitude Mw=7.2 and acceleration a=0.37

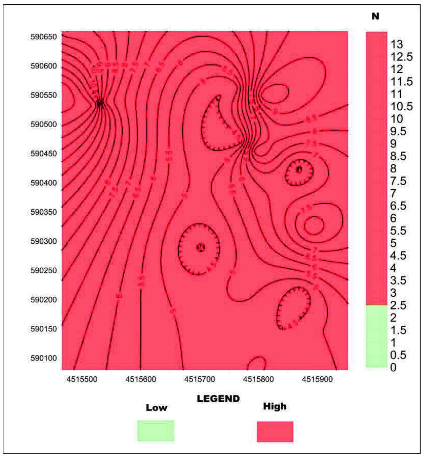


Fig.12. Liquefaction induced settlements map depending on earthquake magnitude Mw=7.2 and acceleration a=0.40

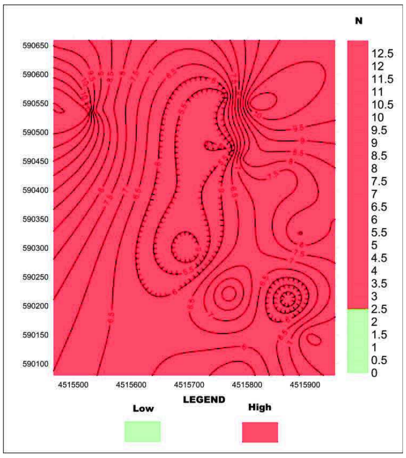
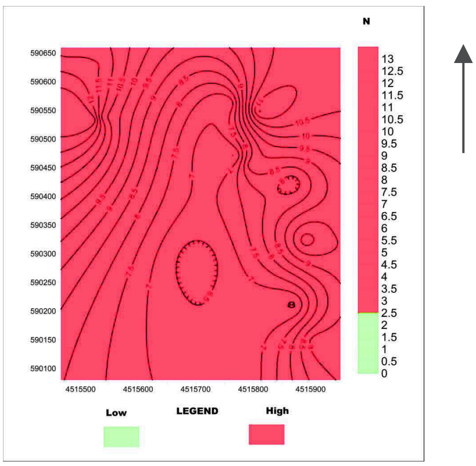


Fig.13. Liquefaction induced settlements map depending on earthquake magnitude Mw=7.2 and acceleration a=0.5



Chapter 7

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 the deterministical (according to fault segment length). 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) by determinictical approaches.

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 deterministic approaches. It was concluded that city of Duzce was assessed as likely to prone the liquefaction zone. The out comes of this study reveals that there is distinct difference on the liquefaction levels between the deterministic approaches. In the light of these experiences, it may be usufull for the city planner and engineers to take into account the both approaches to construct special structures and to open the new residential ares.

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References

[1] Abraseys, NN., Zapotek, A. (1968), "The Mudurnu valley (West Anatolia, Turkey) earthquake of 22 July 1967", Bull, of the Seis. Soc. **59** (2): 521-589.

[2] Ambraseys, N.N. (1995), "The prediction of earthquake peak accelaration in Europe Earthquake Engineering and Structural Dynamics", **1**(1), pp.467-490.

[3] Ambraseys, NN., (1998), "Engineering seismology", Earthq Eng Struct Dyn **17** (1):1–105.

[4] Ansal, A. (1997),"Determination of earthquake design properties for Istanbul" Symposium of Prof.Dr. Rifat YARAR, TDV-KT97-003, Istanbul, December, P.233-244.

[5] Ansal, AM. (1991), "Evaluation of liquefaction susceptibility", Proc. 5th Int. Conf. on Soil Dynamics and Earthquake Engineering, Elsevier, London. pp. 303-312.

[6] American Society for Testing Materials Standard method for penetration test and split-barrel sapmling of soils (ASTM D-1596). In: Annual Book of ASTM standards, sec. **4(**4-9), 1092, 1994.

[7] American Society for Testing and Material: Standard Method for Penetration test and split barrel sampling of soils, Annual Book os ASTM Standards, Soil and Rock (1), Standard No. D 1586-99, 04.08, West Conshohocken, PA,139-143,2000.

[8] Barka, A., Gülen, L. (1988), “New constrains on age and total offset of the North Anatolian Fault Zone:implications for tectonics of eastern Mediterranean region”, METU Journal of Pure and Applied Science, **21**(1-3), 39-63.

[9] Barka, A. (1992), “The North Anatolian fault zone, Ann. Tecton”, **6** (1), 164-195.

[10] Campbell KW (1997), “Empirical near-source attenuation relationships for horizontal and vertical components of peak ground acceleration, peak ground velocity, and pseudo-absolute acceleration response spectra”, Seismol. Res. Lett. (68)1: 154-179.

[11] CDMG, (1999), “Guidelines for analyzing and mitigating liquefaction hazards in California”, California Dept Conservation, Division of Mines and Geology, Special Publication,**1** (17), pp.63

[12] Demirtas, R. (2000), “Neotechtonical properties and seismicity of Northern Anatolian Fault in the part between Abant and Gerede District” Ph.D Thesis. University Of Ankara, Turkey (In Turkish).

[13] Devey, JF., Şengör, AMC. (1979), Aegean and surroundings regions: Complex multiple and continuum tectonics in a convergent zone, Geol Soc. Am Bull **90** (1), 80-92.

[14] Dixit, J., Dewaika,r DM., Jangrid, RS. (2012),“ Assessment Of liquefaction potential index for Mumbai City”. Nat. Hazards, **12** (1), 2759-2768.

[15] Donavan, N.C. (1973) “A statistical evaluation of strong motion data including the February 9, 1971 San Fernando earthquake”, Pages 1252-1261 of:Proceedings of Fifth World Conference on Earthquake Engineering, Vol 1.

[16] Douglas, M B., RyalL, A. (1975), “Return periods for rock acceleration in western Nevada, BSSA, **65**(1) 1599-1611.

[17] Duzce Earthquake, Turkey, [on-line], Bosphoros University Kandilli Observatory and EarthquakeResearchInstitute, 1999-[http:www.koeri.boun.edu.tr./earthqk/earthqk.html]

[18] Gutenberg, B. and Richter, C. F. (1956), “Magnitude and energy of earthquakes”, Ann. Geofis., **9** (1), 1-15.
Gutenberg, B. and Richter, C. F. (1954), “Seismicity of earth and related phonomena”, 2nd. Ed. Princeton Univ. Pres, Princeton, New Jersey.

[19] Finn, WDL. (1993). “Evaluation of liquefaction potential”, Soil Dynamics and Geotechnical Engineering Secoe Pintoed., Balkema, Rotterdam, pp. 127-157.

[20] Gökten, E., Ozaksoy, V., Demirtaş, R. (1998), “Some Neotectonical properties of the North Anatolian Fault zone between Bayramoren-Abant (Turkey)”, Active Tectonic Research Group fisrt meeting proceedings, 68-77, ITU Mining Faculty-Eurasia Earth Science Institute.

[21] Joyner, WB., Boore, DM. (1981), “Peak acceleration and velocity from strong motion records including records from the 1979 Imperial Valley”, California, Earthquake, BSSA. **1**(71) 2011-2038.

[22] Inan, E., Çolakoğlu, Z., Koç, N., Bayülke, N. ve Çoruh, E. 1996. (1976-1996), “Earthquake catologs with accelaration records from 1976 to 1996. General Directorate of Disaster Affairs”, Earthquake Research Division, Anakara, Turkey, 98 pp., (in Turkısh).

[23] Liao, S.S.C. and Whitman, R.V. (1986), “Overburden correction factors for SPT in sand”, Journal of of Geotechnical Engineering, ASCE, (112)**3**, 373-377.

[24] Luna, R., Frost, JD.(1998), “Spatial liquefaction analysis system”, J. Comput. Civil Eng., **12** (1), 48–56.

[25] Obermeier, S.F. (1996), “Use of liquefaction-induced features for paleoseismic analysis -An overview of how seismic liquefaction features can be distinguished from other features and how their regional distribution and properties of source sediment can be used to infer the location and strength of Holocene paleo-earthquakes”, Engineering Geology, **44**(1-4) 1-76.

[26] Iwasaki, T., Tokida, K., Tatsuko, F., Yasuda, S.(1978), “A Practical method for assessing soil liquefaction potential based on case studies at various sites In Japan”, Proceedings Of 2nd International Conference On Microzonation, San Francisco, 885–896.

[27] Ketin, I. (1948), “Über Die Techtonish-Mehanishen Folgerungen Aus Den Grossen Anatolischen Erdbeben Des Letzen Dezenniums”, Geol. Rundsch. **36** (1), 77-78.

[28] Koçyiğit, A. (1989), “Suşehri basin an activa fault zone, Turkey, Tectonophysics”, **167** (1),13-29.

[29] Mark, RK. (1977), “Application of linear statistical model of earthquake magnitude versus fault length in estimating maximum expectable earthquakes”, Geology, **5** (1), 464-466.

[30] Microzonation for Earthquake Risk Management, (MERM),(2003),“Micro-zonation manual”, World Institute for Disaster Risk Management.

[31] McKenzie, D. (1972), “Active tectonics of the Mediterranean region”, Geophys J R Astr Soc. **30** (1),109-185.

[32] McKenzie, DP. (1978), “Active tectonics of the Alpine Himalayan Belt: The Aegean Sea and The Surrounding Regions, Geophys”. J.R. Astr. Soc. **55** (1), 217-258.

[33] Ozçep, F., and Zarif, H. (2009), “Variations of soil liquefaction safety factors depending on several design earthquakes in the city of Yalova (Turkey)”, Scientific Research and Assay 4(6),594-604.

[34] NEMC. (2014), “B.U. Kandilli observatory and earthquake research instıtute”, Natıonal Earthquake Monıtorıng Centre, http://www.koeri.boun.edu.tr/sismo

[35] Patwardan, AS., Kulkarni, RB., Tocher, D. (1980), “A Semi-markow model for charecterizing recurence of great earhquakes”, BSSA, **70** (1), 323-347.

[36] Robertson, PK., Campanella, RG. (1985), “Liquefaction potential of sands using the CPT”, J. GED, ASCE, (111) **3**, 384-403.

[37] Seed, H.B., Idriss, I.M. (1971),“Simplified procedure for evaluating soil liquefaction potential”, Journal of the Soil Mechanics and Foundations Division, ASCE, **97** (9),1249-1273.

[38] Seed, HB., Tokimatso, K., Harder, LF.(1985), “The influence of SPT procedures in soil liquefaction resistance evaluation”, Geotech Engrg, ASCE, **111**(12).

[39] Seed, HB., Cetin, K.O., Moss, RES. (2001), “Recent advances in soil liquefaction engineering and seismic site response evaluation”, Proceedings: Fourth international conference on recent advances in Geotechnical Earthquake Engineering and Soil Dynamics and Symposium In Honor Of Professor W.D. Liam Finn San Diego, California. pp. 26-31.

[40] Seed, R.B., Cetin, K.O., Moss, R.E.S., Kammerer, A.M., Wu, J., Pestana, J.M., Riemer, M.F., Sancio, R.B., Bray, J.D., Kayen, R.E., and Faris, A. (2003),

"Recent advances in soil liquefaction engineering a unified and consistent framework", 26 th annual ASCE L.A. Geotechnical Spring Seminar, Long Beach, California, 71 pp.

[41] Seed, HB., De Alba, P. (1986), "Use of SPT and CPT tests for evaluating the liquefaction resistance of sands", Proc., In Situ'86, ASCE. pp. 281- 302.

[42] Sengör, AMC. (1979b), "The North Anatolian transform fault: its age, offset and tectonic significance", J. Geol. Soc. London, **136** (1), 269-282.

[43] Sengör, AMC. (1979a), "On same 50 % extension In Aegean area and its implications for orogenic econtructions in the Taurides", Papp. Comm. Int. Mer. Medit., 25/26,2a, pp. 41-42.

[44] Şaroğlu, F., Emre, Ö., Kuşçu, I. (1992), "Active fault map of Turkey", General Directorate of Mineral Research and Exploration, Ankara, Turkey.

[45] Tasman, C. (1944), "The report about the Gerede-Bolu Earthquake", DAD/At.46 (In Turkish).

[46] TC4, 1999, "Manual for zonation on seismic geotechnical hazards (Revised Version)", Technical Committee of Earthquake Geotechnical Engineering ISSMGE, pp. 219

[47] Tokimatsu, K., Yoshimi, Y. (1983), "Empirical correlation of soil liquefaction based on SPT N value and fines content", Soils and Foundation, **30** (3), 153-158.

[48] Toksoz, MN., Shakal, AF., Michael, AJ. (1979), "Space-time migration of earthquakes along the North Anatolian Fault Zone and Seismic Gaps PAGEOF", **117** (1), 1258-1270.

[49] Tubitak-AU-MTA.(1999), "Investigation of alternative settlement area after 17 August 1999 Earthquake In Duzce District (Bolu)", Ankara (In Turkish).

[50] Ulusay, R., and Tuncay, E., Sonmez, H., and Gokceoglu, C. (2004), "An attenuation relationship based on Turkish strong motion data and iso-acceleration map of Turkey", Engineering Geology **74** (1), 265–291.

[51] Varnes, DJ. And IAEG Commission on Landslides and other Mass-Movements, (1984), "Landslide hazard zonation: A review of principles and practice. UNESCO Press", Paris, 63pp.

[52] Wells, DL., Coppersmith, KJ. (1994), "New empirical relationships among magnitude, rupture length", rupture width, rupture area, and surface displacement. Bulletin Of The Seismological Society Of America. **84** (4), 974–1002.

[53] Youd, TL. and Idriss, IM. (1997), "Evaluation of liquefaction resistance of soils", Proceedings of the NCEER Workshop, Technical Report NCEER-97-0022, National Center for Earthquake Engineering Research.

[54] Youd, T.L. (1998), "Screening guide for rapid assessment of liquefaction hazard at highway bridge site", Technical report, MCEER-98-005, pp. 58

[55] Youd, TL.,Idriss IM., Andrus RD, Arango I, Castro G, Christian JT, Dobry R., Finn WDL, Harder Jr LF, Hynes ME, Ishihara K, Koester JP, Liao SSC, Marcuson WFIII, Martin GR, Mitchell JK, Moriwaki Y, Power MS, Robertson PK, Seed RB, Stokoe KHIII.: Liquefaction resistance of soils: Summary report from the 1996 NCEER and 1998 NCEER/NSF workshops on evaluation of liquefaction resistance of soils. J Geotechn Geoenviron Engng, ASCE; **127** (10),817-33, 2001.