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INVESTIGATION OF DAMPING ACCELERATION RATIO AND SITE EFFECTS ON SEISMIC GROUND RESPONSE IN THE DUZCE REGION, TURKEY

Keywords: *Soil amplification,site conditions peak groundaccelerations*

Abstract

The city of Duzce in Western Black Sea Turkey has a experienced of a destructive earthquake with Mw=7.2 in 1999 Duzce earthquake and is situated on the highly active Eurasian plate. The North Anatolian Fault Zone (NAFZ) crosses through Turkey from east to West; earthquake occurred on this fault on August17, 1999 (Kocaeli) and November 12, 1999 (Düzce). Regional geology and subsoil conditions can change the site characteristics of ground motion. Thus, detecting the soil magnification at the time of occurring an earthquake, especiallyfor weak soils, is crucial subject for investigators. In this research, one dimensional ground response behavior analyses were executed for Gölyaka area utilizing the August 17, 1999 Duzce e record with earthquake strong ground motion with DEEP SOIL software. Soil characteristics and depth to engineering bedrock at the Gölyaka sites are various and the observed level of the constructional hazard at Gölyaka region at the time of occurring the Duzce earthquake was different as well. Findings revealed that higher magnifications ratios occur at higher periods due to soil behaviour. Result of this research revealed that local geological conditions can magnify ground motion at some periods and, according to the amplification, and obtained

response spectra can exceed the suggested design spectra. As a result, it is apparent that local site conditions should be taken into consideration for earthquake-resistant engineering designs on soft soils.

1. Introduction

Turkey is situated on one of the world's major and the most dangerous earthquake zone (Fig. 1). Moreover, the Marmara region, that is a heavily industrialized and populated area placed in the Northwestern Black sea in Turkey. This region is subjected to devastating earthquakes. The August 17, Adapazarı and Kocaeli 1999 and November 12, 1999 Duzce earthquake are examples of recent destructive earthquakes. Especially, the November 12, 1999 Duzce earthquake affected a large part of the Duzce and its environments. One of the most important properties of hazards is foundation concerned defects of structures, such as tilting, overturning and sinking. Duzce area is situated on young flood-plain deposits of the alluvium sediments around the Efteni Lake. For this reason, soft soil-deposits are considered to play an important role in these damages. The amplitude of seismic waves goes up while they go through weak soil strata near the earth's surface. This kind of study is called the site amplification. There are some investigators who have surveyed the effect of local site conditions on structure defects in literature [Çetin et al. 2002; Tezcan et al. 2002; Sancio et al. 2002; Ozel and Sasatani 2004; Fırat et al. 2009]. Pertinent investigations have revealed that site effects may be noticed to detect the behaviour of structures under the effect of the seismic load.

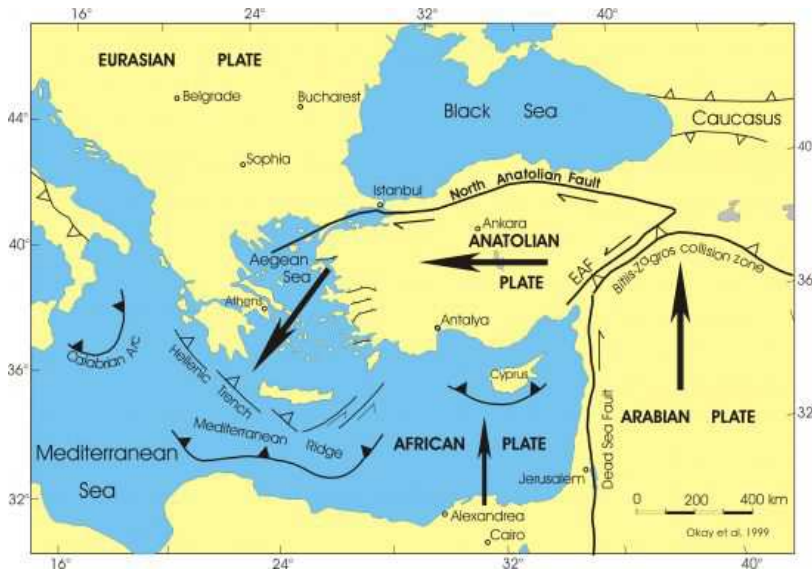


Fig. 1. Main tectonic properties of Turkey [Gülen et al.2000]

Local ranges on the attributes of alluvial sediments in Duzce come out to play an important role in the occurrence and non-occurrence of ground defects and joined structures. Basic judgement of site data offers that type and width of buildings has no clearly affect the degree of ground defects. Nevertheless, localization of noticed displacements around structures, the relatively scarce notice of liquefaction in around, and the higher rate of strong ground defects for higher structures offers that ground strains joined with soil-structure interaction could have contributed to the triggering and intensity of ground defect [Sancio et al., 2002].

In this research, registered strong ground motion datum were utilized to detect the soil magnification ratio in Duzce basin. Correspondance in basin were conducted by the help of the DEEPSOIL computer program which is a capacity of enabling one-dimension response analysis. In these correspondances, the confining pressure dependent model [Ishibashi and Zhang 1993] was utilized for ground soil behavior response findings. The spectral behaviour acquired for the profiles were compared with the original design spectrums offered in the Turkishquake Code (2007) and the Eurocode 8 (CEN 2004).

2.Geology of the Adapazarı Region

Düzce Basin was formed by the activities of the North Anatolian Fault (NAF) and the Duzce basin is bounded by the active Gölyaka-Eftani-Beyköy Fault in the south and the Çilimli-Konuralp Fault in the north. The Çilimli-Konuralp Fault is relatively less active than the Gölyaka-Eftani-Beyköy Fault according to the historical and instrumental sources. These faults are part of the south and north segments of the NAF and they are the main branches shaping the morphology of the region. The Düzce Plain has occurred forming the mid-section of the basin presents a low inclined topography towards the southwest to Eftani Lake. The drainage network which has developed based on the morphology of the basin has NE-SW and E-W flows and leads to Melen creek. The Küçük Melen River and Asarsuyu Creek flows the surface waters of the basin into Lake Eftani. The Büyük Melen River subsequently discharges the waters of Lake Eftani to the Black Sea with a S-N flowing direction (Fig. 2). The hydrologic and morphologic properties in the basin are the results of the intense tectonic activity that controls the basin structure and overall slope of the plain.

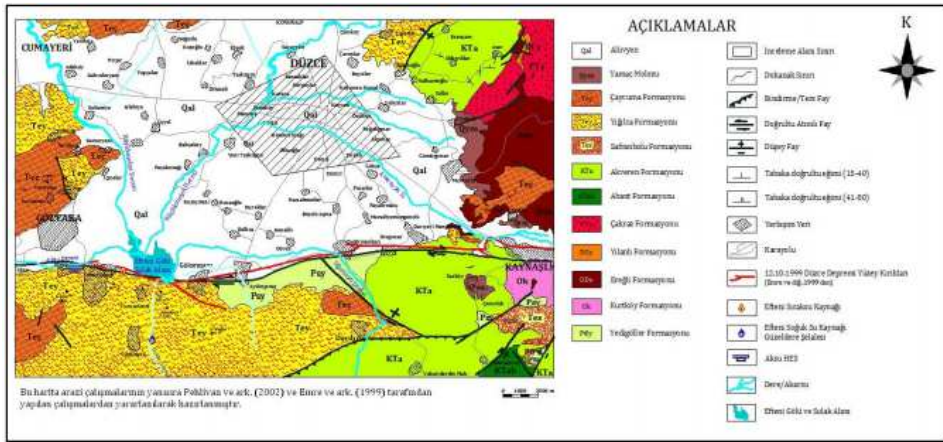


Fig.2. Geological map of the Duzce [MTA, 2002]

The main area of the Duzce basin was occurred with quaternary alluvial deposits containing gravelly and silty sand by the Asar creek and Küçük Melen creek (Fig.2). These sediments contain low-plasticity clay and silt. Quaternary formations are made of holocene alluvial deposits within different startum thicknesses, smooth gravel gradations, sand and silts .

3. Local Site Effects On Ground Motion

Local site effects has an strongly impact all of the significant charecteristics, such as amplitude, frequency content, and duraton of strong ground motion. Their level of effect due to the geometry and properties of subsurface materails, on topography of the region, and on the charecteristics of the input motion [Kramer 1996]. Charecteristics of an earthquake are a role of fault mechanism, distance to the earthquake epicentre, geological structures and local soil conditions. The most important parameters of soil conditions are the elavation of a soil stratum on the bedrock, differences of the soil profile ans its charecteristics with depth, lateral geological heterogenity and surface topography [Birigen 2000]. If the thickness of the soft soil stratum above bedrock increases, prodominant periods of ground shift towards higher periods. More over, if shear wave velocity in soil layer decreases, dominants period of the soil shifts towards higher periods with higher amplifications. As a soil profile consists of various stratum, every stratum having various non-linear stress strain behaviour, the response of soil becomes more complicated. Thus, there are many investigators who have investigated the soil amplifications phenomenon utilizing real earthquake records; Ozgirgin [1977], Biringen [2000], Tezcan et al. [2002], Hasal and Iyisan [2004], Yalcinkaya [2004], Hasancebi and Ulusay [2006] and Kutanis and Ball [2006].

There is no important influence factor on the dominant ground frequency from the point of view the the arrival angle of earthquake waves. But when only the arrival angle increases, a small reduction in amplification values is noticed. From previous studies from the point of view, it is usual to accept that vertical S-waves do not cautilize an important error [Yalçınlkaya 2004]. In the end, soil behaviour to be subjected to earthquake loading due to the soil layer thickness. Thus, ground response analysis where non linear behaviour of soils is taken into consideration are crucial for a safe earthquake-resistant design. In spite of the distance to the epicentre at Duzce was longer, the maximum horizontal peak ground acceleration was traced around this site. It can be occured due to the subsoil conditions.

4. Site Amplificationfactor in the Duzce Area

Three different locations, namely Duzce centre, Duzce Eftani lake, and Gölyaka area were selected sites where is different. In thesse locations, buildings subjected to heavy damage during the August 17, 1999 Kocaeli and November 12, 1999 Duzce Earthquake. Anbazhagan and Sitharam [2009] offered that shear wave velocity of 700 ± 60 m/s is consired to be the trace of engineering rock. Among these locations, Gölyaka area has the greatest depth to engineering bedrock at 180 m. Depths to base bedrock are 80 m for the Efteni Lake area, 60 m for the Duzce Centre location are recorded. Borehole logs acquired and shearwave velocities recorded profiles of these locations are presented in Fig. 3 and 4. These soil profiles are obtained from Municipality of Gölyaka and Duzce. Regarding to Gölyaka field works, study is performed in Golyaka in the scope of the paliioseismological works. Detailed borehole logs are given in Fig. 3 that is cited from Alemdar [20017]'s master thesis. Shear waves of the soil layers were obtained from standard penetrations test (SPT) values utilizing emperical relations and performed surface geological studies.

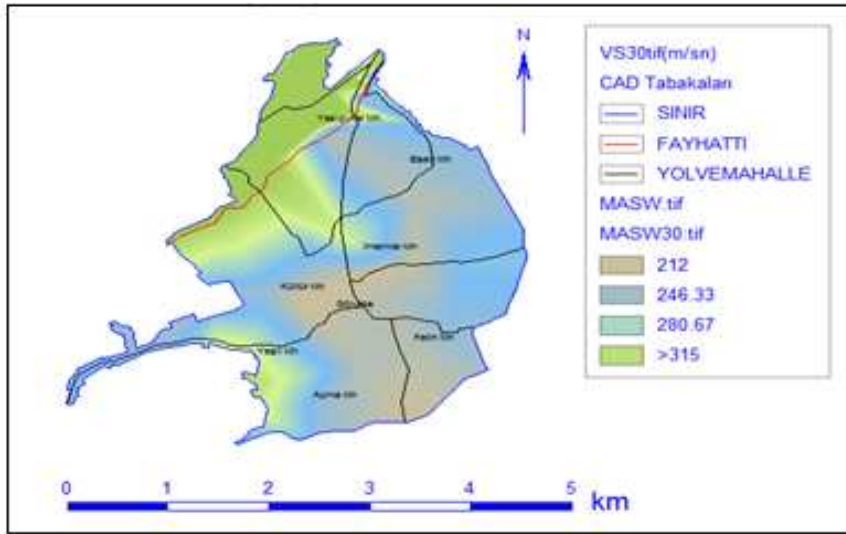


Fig.3. Shear wave velocity V_{30} map in Duzce

For the selected locations, equivalent ground response analyses were conducted utilizing DEEPSOIL V.7 programme. This software is a graphical utilizer interface for DEEPSOIL V.7. It calculates ground response in a visco-elastic homogeneous and horizontally extending infinite system that is affected by shear waves advancing vertically [Ordenez,11]. This program is attributed to the repeated solution of the wave equations which are simulated for utilize in short-term mobility, by the help of a Fourier transformation algorithm. Non-linear shear modulus and damping can be defined by effective deformation in each layer with a compatible shear modulus, and a repeated method is utilized with equivalent linear soil features to obtain damping values. Obtained spectral behaviour of selected locations were compared with the design spectrums submitted in the Turkish Earthquake Code (2007) and the Eurocode 8 (CEN 2004).

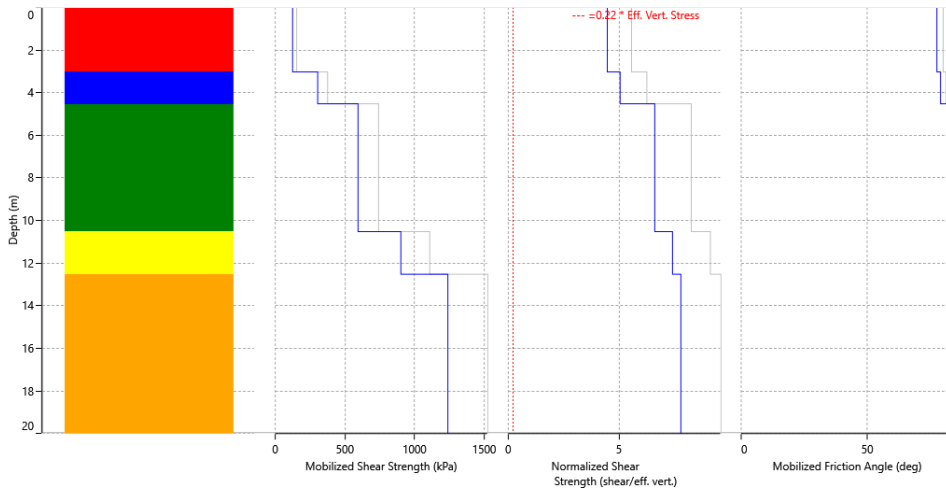


Fig. 4. Shearwave velocities recorded profiles in Duzce

The number of different shear modulus and reduction and damping curves to utilize in equivalent linear ground response analyses were present. Early models are utilized separately for fine-grained and coarse-grained soils. But, further more last studies have shown a gradual transition between non-plastic coarse and plastic-fine soils [Kramer 1996]. Sun et al. [1988] and Vucetic and Dobry [1991] declared that the shape of the modulus reduction curve is completely affected by the plasticity index while Iwasaki et al. [1978] and Kokusho [1980] propose that it is also affected by the effective confining stress, with G/G_{max} increasing with increasing confining stress and plasticity index. whereas damping ratio decreases with increasing confining stress and plasticity index. The effect of confining stress and plasticity index on modulus reduction and damping behavior were associated by Ishibashi and Zhang [1993], Darendeli [2001], Zhang et al. [2005]. To compare these studies, Darendeli [2001] has utilized a 120 m thick silty sand sand deposit with a stress- dependent shear wave velocity profile and they revealed that stress- dependent modulus reduction and damping ratio curves produced almost twice the peak ground acceleration that was considered by the generic curves, and larger spectral accelerations have been Found. Herewith, it is revealed that the utilize of both stress and plasticity index dependent models delivers more realistic ground response for the selected sites than traditional shear modulus and damping models. For this reason, the Ishibashi and Zhang [1993] model is preferred for ground response calculation for this study. Figure 5 denotes %5 damped spectral acceleration which is yielded in Gölyaka.

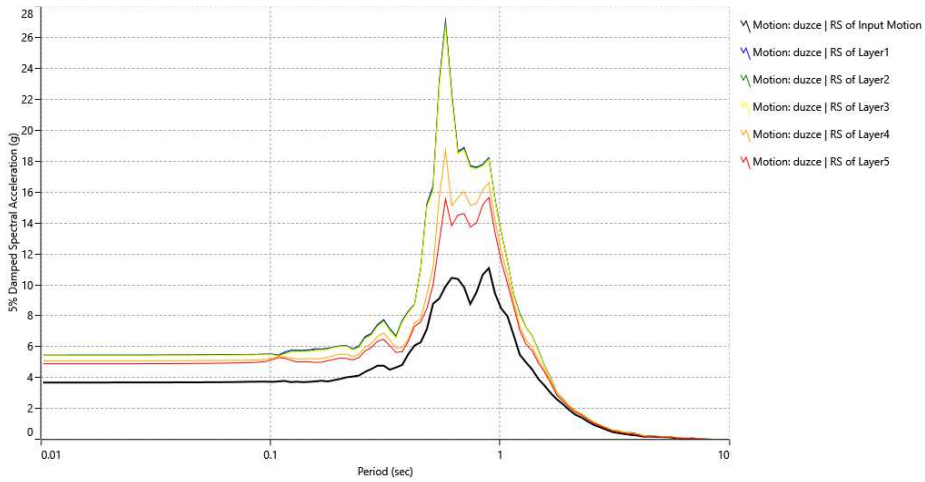


Fig. 5. Ground surface acceleration spectrum yielded based on 1999 Duzce earthquake

In this site, strong-ground motion data in Table 1 was utilized as bedrock earthquake motion [Peer 2007]. This strong ground motion was exerted to the base of the soil layers where engineering bedrock was given as Acceleration time history.

Table 1. Strong ground motion data in analyses

Earthquake	Station	Compound	Maximum Ground Acceleration (g)	Moment Magnitude
November 12 Duzce Earthquake	Meteoroloji	90	0.453	7.2

Acquired response spectra for selected areas were compared with the original design spectra of the stress-strain versus time (Fig. 6). Found response spectra for all sites are compared with the suggested design spectra of the stress-strain and %5 damping acceleration spectrum in Fig. 5 and 6.

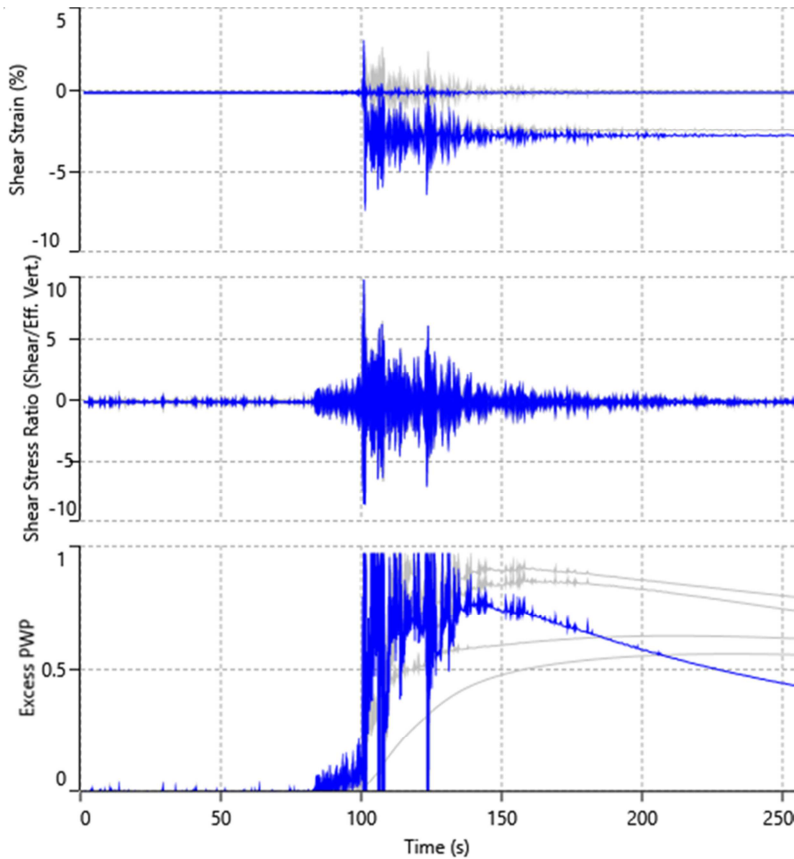


Fig.6. Stress strain versus time

As it is shown from Fig. 6., the obtained surface response spectrum for 5 % damping exceeds the suggested design spectrum represented for the Z4 soil group between 0.2 and 0.5 s periods, that correspond to the predominant period of most of the typical residential buildings at Duzce. D soil type is assigned to soils which are soft-loose, thick alluvium stratum with shear wave velocity lower than 190 m/sec; when thickness of D type soil exceeds 10 m, it is graded as a Z4 group soil according to the Turkish Earthquake Code (2007). However, it is below the design spectrum recommended by the Eurocode 8 (CEN 2004) for soil class D.

For Golyaka sites where the depths to engineering bedrock are significantly lower than that at Duzce centre sites, maximum spectral acceleration values are found within the 0.05-0.2 s periods and these spectral acceleration values exceed the recommended values in both the Turkish Earthquake Code (2007) and the Eurocode 8 (CEN 2004) (Fig.5,6). However, a 0.05-0.2 s period range

is lower than of most of the typical reinforced concrete residential buildings in Duzce city.

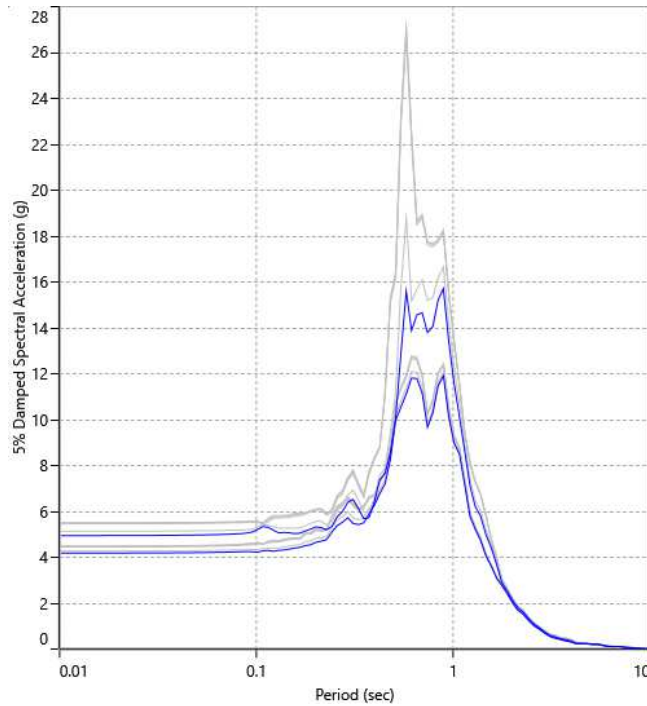


Fig.7. Peak ground horizontal acceleration with damping raio of %5

Seperately, obtained peak ground accelaration are also increased. Figure 7 shows an Acceleration- time graph acquired at the surface of the Golyaka soil profile under November 12, 1999 Duzce earthquake loading. Differences in the strong ground motion parameters are traced through the soil layers where seismic waves go through. Values of peak ground acceleration of ground motion diverge with depth. For soil profiles regarded in the analysis, the peak ground accelerations is reduced from the applied point to the surface, such as up to 60 m in the 90 m Golyaka profile, and up to 40 m in other profiles due to soil damping.

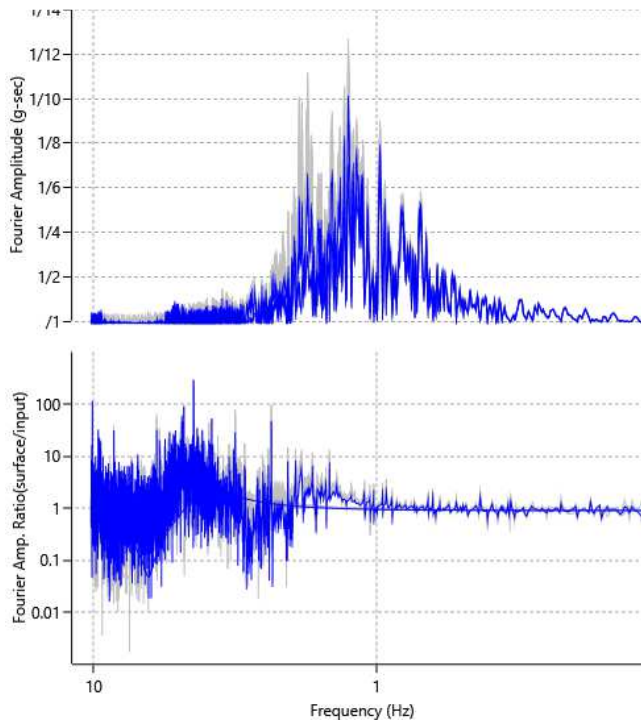


Fig.8. Tranfer function of frequency

The decrease of the peak ground acceleration values at these certain depths is due to bound to damping; continously increasing values above a certain depth shows influence of the surface waves (Fig.8). The transfer function defines how each frequency in the bedrock motion is amplified by the soil stratum. Figure 8 denotes an example transfer function, with larger site amplification acquired at a small frequency-high period due to weak and soft soil behaviour.

During the main shock of the November 12, 1999 Duzce Earthquake, the largest recorded peak accelerations were likely not the largest which taken place. Especially, the record from Golyaka denotes peak acceleration of 0.81 g, larger than any peak recorded during the main shock. More over, during the November 12, 1999 Duzce Earthquake ($M_w=7.2$) Duzce event, at Bolu stations recorded 0.81 g East West [Çelebi et al.2000]. Tezcan et al. [2000] also expressed that the surface acceleration may be as large as 4-5 times those of base rock accelertions.

5. Conclusions

For the Duzce region, study site is situated on a thick alluvial squence, ground response alyses were conducted with the computer program pro shake 2.0 utilizing soil profiles from bore home at the site study that is drilled to describe soil magnification in the study area. While analysing, the November 12, 1999 Duzce Earthquake data was utilized to apply strong ground motion to soil profiles and differences in soil surface due to ground motion exerted on the sub stratum of the regarded soil profile. Spectral behaviour was compared with the design spectra of the Earthquake Code (2007) Z4 type and site class D, and Eurocode 8 (CEN 2004) type 1. Ground responseanalyses conducted in this research utilizing stress- dependent shear modulus and damoing ratio curves of Ishibashi and Zhand [1993] determine that the Found response spectra of the selected exceed the design spectra presented in the Turkish Earthquake Code (2007).

The largest amplification for soil profiles is between 0.67 and 2.7 Hz in the transfer function while analysing. Acceleration of strong ground motions applied to the bottom of the soil profiles changes toward the ground surface. Due to the ground response analyses conducted utilizing the Duzce Earthquake registration, maximum peak ground acceleration is acquired at the Duzce Center. This site was significantly affected by the Duzce Earthquake. Some of the buildings at the Duzce center were damaged. It has been noticed for years that local site and soil conditions can affect the amplitudes, frequency and duration of seismic waves while they propagate through soil stratum around the ground surface. The November 12, 1999 Duzce Earthquake with a magnitude ($M_w=7.2$) struck the Marmara and Duzce regions in the North-Western area in Turkey. The earthquake cautilized considerable reasons and heavy damage to buildings. Among some cities influenced, Duzce in Marmara region significantly suffered the worst damage becautilize of the geotechnical effects and site response.

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