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Short Communication

Earthquake and impact of soil type on content of the result spectrum

Authors:
Shahryar Heidari and Siyamak Bagheriyan

Institution:
Department of Civil Engineering, Shahryar Branch, Islamic Azad University, Tehran, Iran.

Corresponding author:
Shahryar Heidari

ABSTRACT:

There are various factors which effect on spectrum of earthquake such as: soil type, magnitude of earthquake, distance to earthquake center, type of fault, duration and damping of earthquake. The research was aimed to investigate the effects of soil on the spectrum of earthquake. Therefore, several accelerograms for three different locations around the world have been selected from Berkeley University website. Then the selected accelerograms were scaled up with number 1 for scaling the spectrums. The spectrums of accelerograms and the records of earthquake were drawn by seismosignal software. Finally, the effect of different soil were investigated on the spectrum of response earthquake. For increasing the accuracy of results, similar effective parameter have been selected in choosing of accelerograms. Results of the research were as follows; the domain of spectrum was higher due to increasing the hardness of soil in harez um similar design factor in low periods and the domain of spectrum was higher due to increasing the softness of soil in higher periods. The diagrams are more gatherer and possess a greater amount in harder soil and are is more extent and possess a lower amount in the softer soil.

Keywords:

Response spectrum, earthquake, soil type, accelerogram, seismosignal.

Email Id:

shahryar_haidari@yahoo.com

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INTRODUCTION

Transferring the load of structures is done directly or indirectly by foundation to the soil. Especially during an earthquake, behaviours of structures are effected by the soil conditions under the foundation and soil properties that poses important role in the transferring of seismic waves from the bedrock to structures. The accuracy of transmission mechanisms of waves, determination and applying lateral force caused by the earthquake is a main issue in safe and optimized designing structure. The diffused fluctuations caused by the earthquake of bedrock can be intensified or weakened due to the characteristics of soil and the structure. The project was aimed to investigate and compare the effects of soil on spectrum earthquake for three different locations all around the world. For increasing the accuracy of results, similar effective parameters have been selected in the choosing of accelerograms. The reflectance spectrum of an accelerogram indicated the factors such as ground motion acceleration, frequency content and duration ground motion at Location.

The spectrum of location against earthquakes are well-known in the designing of structures. Based on the conducted research, there are two methods for considering the intense vibration caused by the earthquake and its impact on the structure during an earthquake (earthquake design) Imanpour and Mehobbi, 2008

1. The reflection spectrum of project is obtained from the spectrums of different reflection records.
2. The obtained spectrum was converted into an elastic design by averaging of four accelerograms.

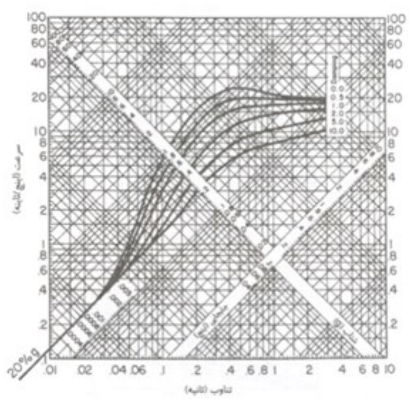


Figure 1. Triple graph of spectrum *Havzner* design (Moghadam, 1992)

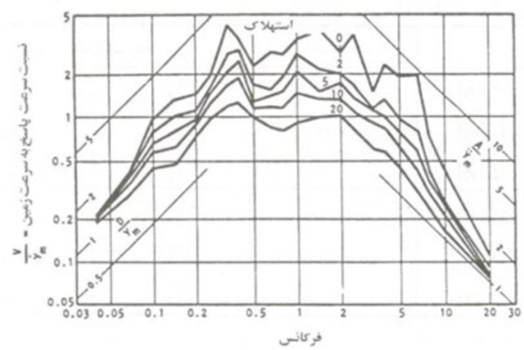


Figure 2. Coordinated response spectrum (no dimensions) of *EL Centro* earthquake (Moghadam, 1992)

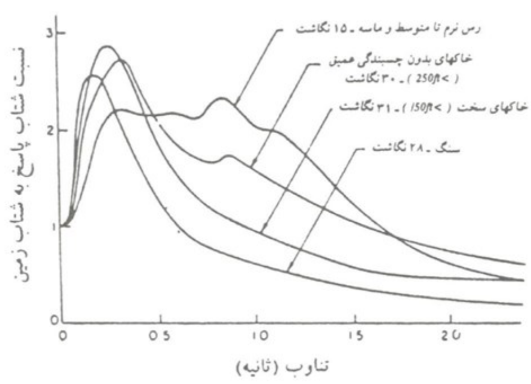


Figure 3. Acceleration spectrum average (50%) no dimensions for different types of ground (Moghadam, 1992)

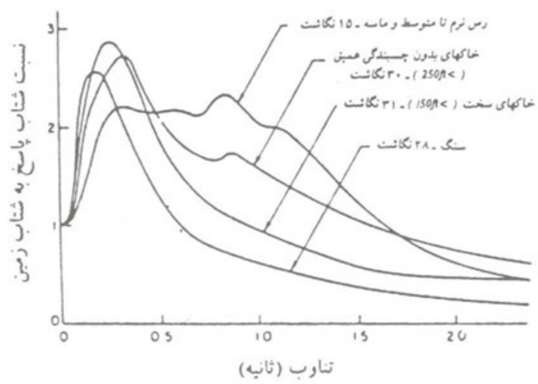


Figure 4. Acceleration spectrum above-average (84.1%) No *sayed* dimensions for different types of ground (Moghadam, 1992)

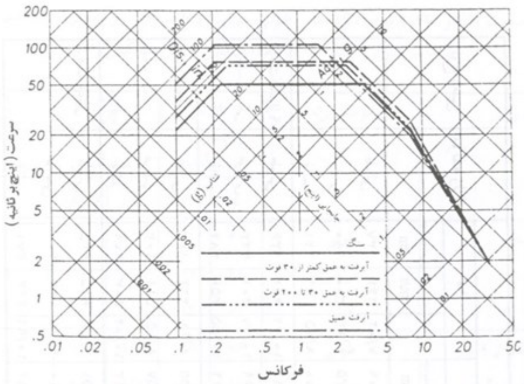


Figure 5. Spectrum of Moahrez design for depreciation 5% and ground acceleration 1g/ (Moghadam, 1992)

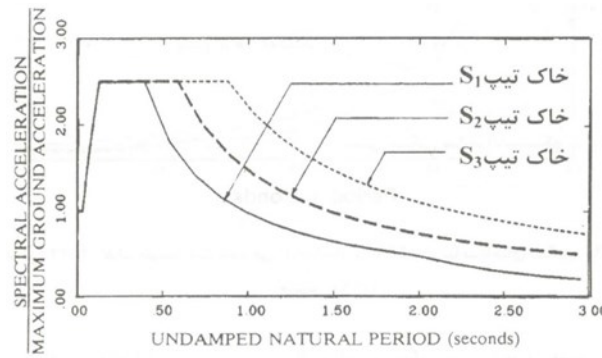


Figure 6. Normalized response spectrum, damping 5% (Bazyar and Ghanad, 2003)

MATERIALS AND METHODS

Some researchers had evaluated various factors on the shape of the reflection spectra. Most of the cases are as follows Imanpour and Mehobbi, 2008:

1. Specifications of soil location
2. Magnitude of earthquake and ground motion parameters including acceleration, velocity and displacement

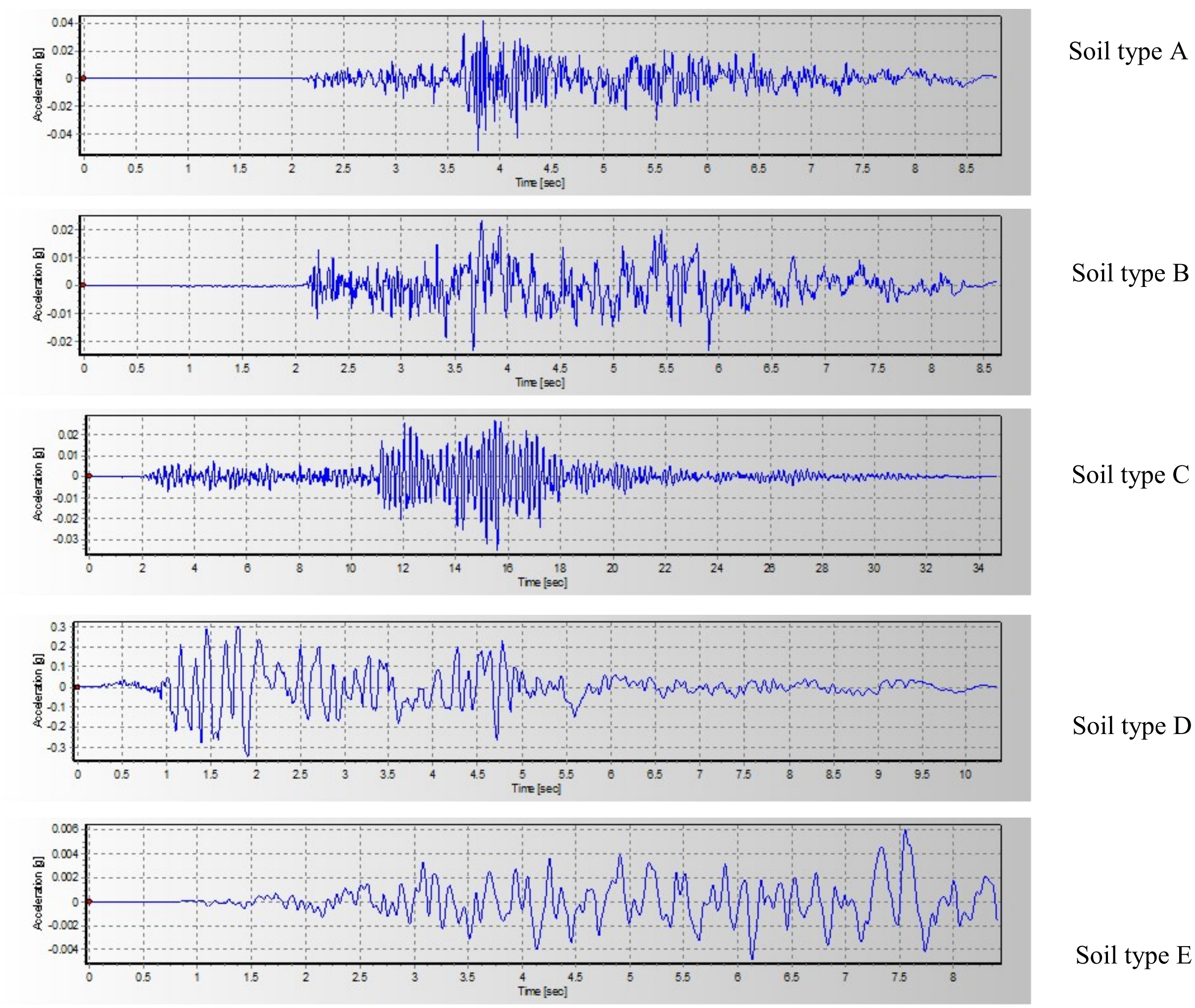


Figure 9. Recorded accelerograms of *Duzce* earthquake (Duzce, Turkey 1999/11/12)

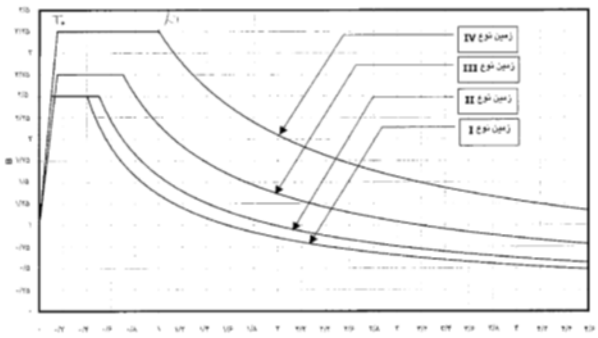


Figure 7. Building reflection coefficient for a variety of lands for earthquake with low and moderate risk [BRC, 2005]

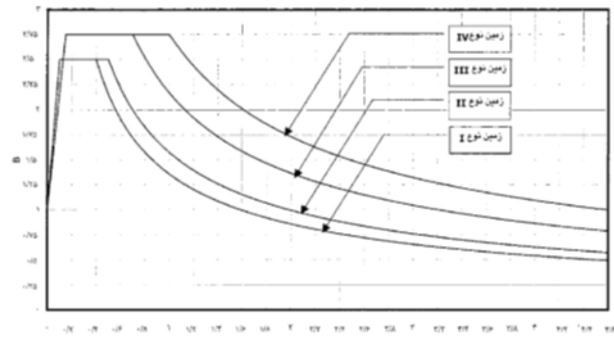


Figure 8. Building reflection coefficient for a variety of lands for earthquake with high and very high risk [BRC, 2005]

maximum Earth

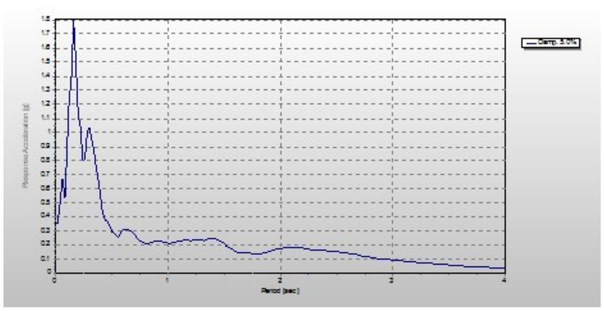
3. The distance to the epicenter of the earthquake site and the type of soil classification in the passage of seismic waves to site

4. The characteristics and mechanisms of origin earth quakes and duration of ground motion in time of earthquake

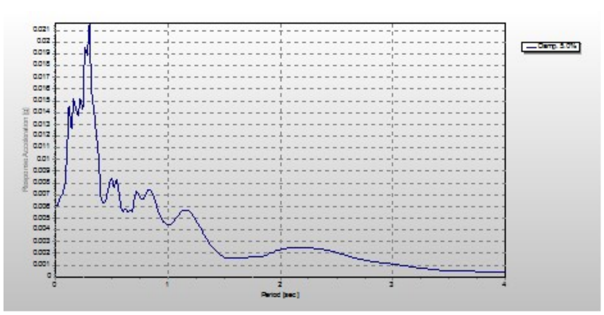
Therefore, a real spectrum includes the above factors. There are some methods to calculate the resistance of structure against earthquakes. The most common methods are equivalent static analysis, modal and dynamic Moghadam (1992). One of these methods are using the spectrum seismic reflection in structure Amiri, 2003. The seismic force can be determined in quasi-static method by follow simple equation Moghadam (1992):

Earthquake Force = Structural weight * Acceleration of spectrum

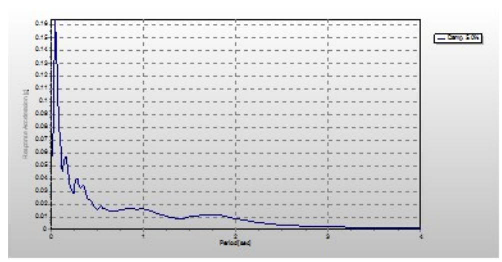
In this way, Structural force can be calculated by using the spectrum acceleration of the earthquake.



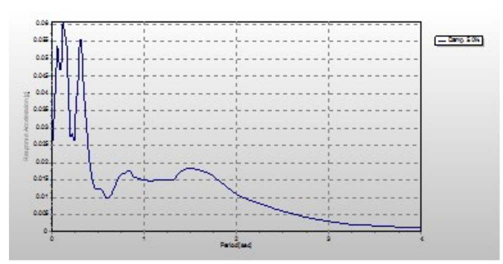
Soil type D



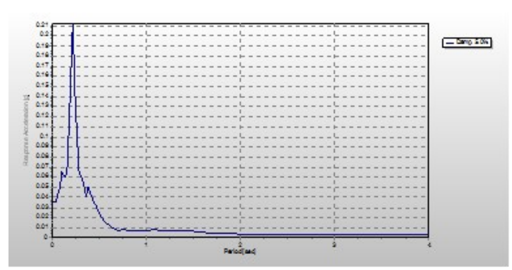
Soil type E



Soil type A



Soil type B



Soil type C

Figure 10. The spectrum of *Duzce* earthquake (Duzce, Turkey 1999/11/12)

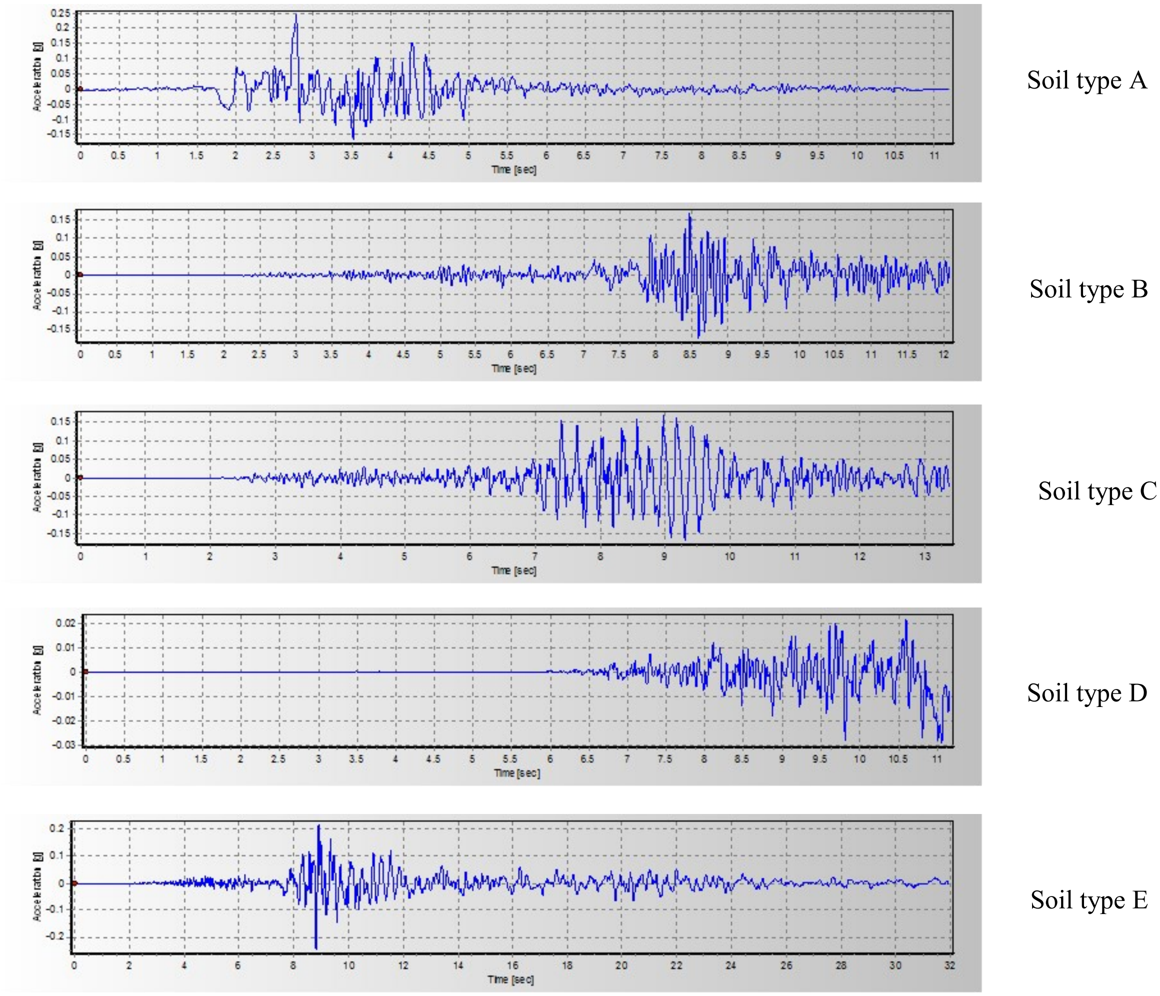


Figure 11. Recorded accelerograms of *Kocaeli* earthquake (Turkey 1999/08/17)

Soil type is one the most important factors which have a significant impact on the amount of spectrum. There are different methods for soil classification as follows: regional geological method, speed method, using SPT, microtremor method (microtremore) and the shape of response spectrum method Amiri, 2003. Havzner was the first researcher who presented the design of spectrum earthquake in the late of 1950's. The Havzner designing spectrum for acceleration, velocity and displacement are shown in Figure 1. This spectrums are appropriate for analysis and designing in field of reactionary, while more structure are related to inelastic field. The spectrums are co-ordinated on base of ground acceleration 0.2 g and they should be divided on 0.2g for certain ground acceleration A. In the late 60s, Newmark and Hall studied the triple spectrum of many accelerogram. They noted there are several specified areas in triple spectrum diagram which the results are presented for El Centro earthquake in Figure 2 (Moghadam, 1992).

1. Acceleration response is equal to acceleration ground in high frequency.
2. Acceleration response is almost constant in range of two to eight Hz.
3. Velocity is almost constant In range of 0.2 to 2 Hz.
4. Relocation is almost constant in the range less than 0.2 Hz.
5. Relocation of structure is equal to relocation of ground in very low frequency.

The effect of type ground wasn't considered in initial spectrum of Newmark and Hall. Other researchers noted that there were difference between the content of the recorded frequency of accelerograms on bedrock

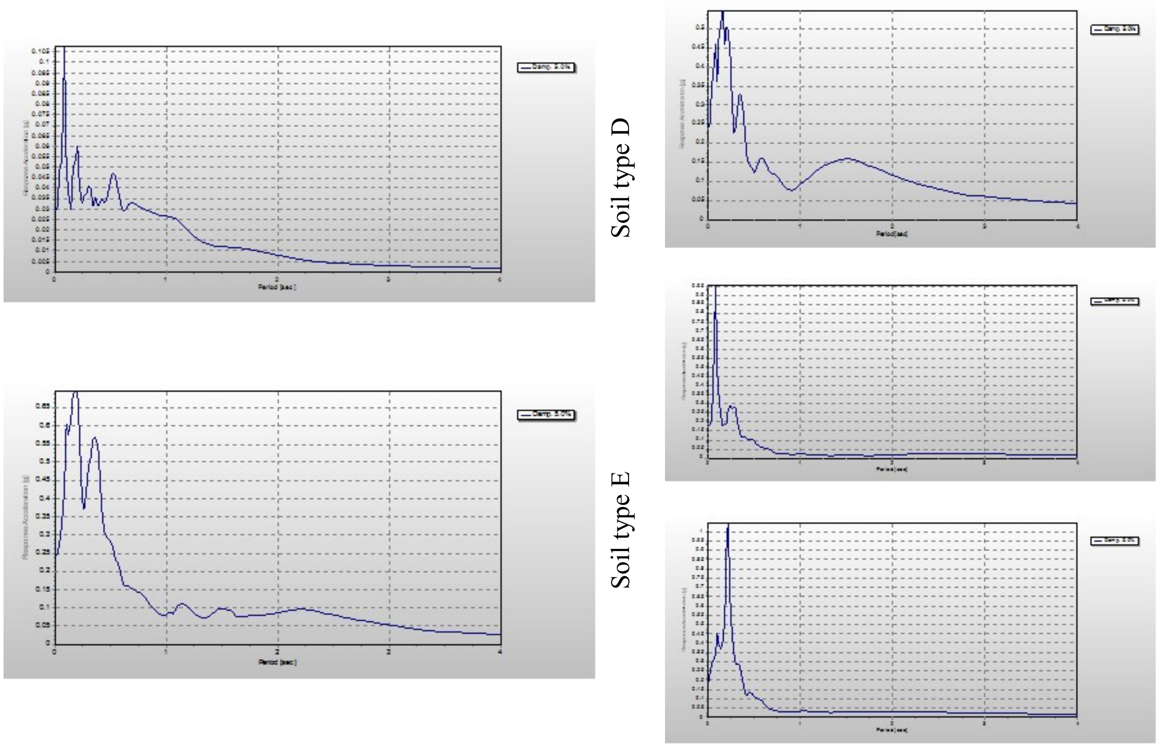


Figure 12. The spectrum of *Kocaeli* earthquake (Turkey 1999/08/17)

and recorded frequency on illuviation. The results of the research indicated in Figures 3 and 4 (Moghadam, 1992). The effect of the soften ground type appeared as decreasing the amplification factor of acceleration in high frequencies and also increasing of the factor in low frequencies. (Moghadam, 1992)

The curves of Figure 6 were obtained by the results of seismic designing structures Bazyar and Ghanad (2003). Regulations of buildings design against earthquakes (Iran 2800) presented the spectrum design for soil types and intensity of relative risk by using the newest results (version 3, 1382) in accordance with

Table 1. Classification of land

S. No	Approximately Vs (meters per second)	Description of ingredients	Type of land
1	More than 750 More than 750	(A) Igneous rocks (coarse and fine texture), hard and very resistant rocks and metamorphic mass (gneiss-crystalline silicate rocks) conglomerate classes (B) Hard soils (sand dense, very hard clay) with a thickness of less than 30 m	I
2	375≤Vs≤750 375≤Vs≤750	(A) Loose igneous rocks (eg tuff), sedimentary rocks, foliated metamorphic rocks, loose rocks generally caused by weathering (degraded). (B) Hard soils (sand dense, very hard) with a thickness greater than 30 m	II
3	375≤Vs≤175 375≤Vs≤175	(A) Shattered rocks by the weathering. (B) In soils with medium density, layers of sand and clay with medium bond between don and clay with moderate hardness.	III
4	Less than 175	(A) Soft sediments with high humidity due to the high ground water level (B) Any kind of soil profile consisting of at least 6 meters of clay with plasticity index greater than 20 and more than 40 percent moisture.	IV

Table 2. Recorded Information of *Duzce* earthquake (Duzce, Turkey 1999/11/12)

S. No	Site conditions	Distance (km)	Magnitude	Data source	Station	Soil type
1	Geomatrix or CWB (A)	Closest to fault rupture (30.2) Hypocentral() Closest to surface projection of rupture (30.2)	M (7.1) Ml (7.2) Ms (7.3)	LAMONT	Station:1060 Lamont 1060	A
2	Geomatrix or CWB (B)	Closest to fault rupture (27.4) Hypocentral() Closest to surface projection of rupture (27.4)	M (7.1) Ml (7.2) Ms (7.3)	LAMONT	Station: 362 Lamont 362	B
3	Geomatrix or CWB (C)	Closest to fault rupture (172.5) Hypocentral() Closest to surface projection of rupture (172.5)	M (7.1) Ml (7.2) Ms (7.3)	KOERI	Station: Fatih	C
4	Geomatrix or CWB (D)	Closest to fault rupture (8.2) Hypocentral() Closest to surface projection of rupture (8.2)	M (7.1) Ml (7.2) Ms (7.3)	ERD	Station: Duzce	D
5	Geomatrix or CWB (E)	Closest to fault rupture (193.3) Hypocentral() Closest to surface projection of rupture (193.3)	M (7.1) Ml (7.2) Ms (7.3)	KOERI	Station: Ambarli	E

The second selected earthquake was *Kocaeli* earthquake (1999).The record of this earthquake has been registered on different soils and corresponding spectrum of each accelerogram has been drawn. All of accelerograms data are presented for different soils in Table 3 and Figure 11. *Kocaeli* earthquake spectrum is shown in Figure 12.

Figures 7 and 8. According to the regulations, classification of ground is presented in Table 1 [BRC, 2005].

Soil classification

Four soil classifications were used to evaluate the effect of soil on response spectrum

A: Rock

B: Shallow (stiff soil)

C: Deep narrow soil

D: Dep broad soil

E: Soft deep soil

Choosing the earthquake

The first selected earthquake was Duzce earthquake (1999). The record of this earthquake has been registered on different soils and corresponding spectrum

Table 3. Recorded information of *Kocaeli* earthquake, (Turkey 1999/08/17)

S. No	Site conditions	Distance (km)	Magnitude	Data source	Station	Soil type
1	Geomatrix or CWB (A)	Closest to fault rupture (17.0) Hypocentral() Closest to surface projection of rupture (17.0)	M (7.4) Ml () Ms (7.8)	ERD	Station: Gebze	A
2	Geomatrix or CWB (B)	Closest to fault rupture (76.1) Hypocentral() Closest to surface projection of rupture (76.1)	M (7.4) Ml () Ms (7.8)	KOERI	Station: Cekmec e	B
3	Geomatrix or CWB (C)	Closest to fault rupture (64.5) Hypocentral() Closest to surface projection of rupture (64.5)	M (7.4) Ml () Ms (7.8)	KOERI	Station: Fatih	C
4	Geomatrix or CWB (D)	Closest to fault rupture (67.5) Hypocentral() Closest to surface projection of rupture (67.5)	M (7.4) Ml () Ms (7.8)	ITU	Station: Atakoy	D
5	Geomatrix or CWB (E)	Closest to fault rupture (78.9) Hypocentral() Closest to surface projection of rupture (78.9)	M (7.4) Ml () Ms (7.8)	KOERI	Station: Ambarli	E

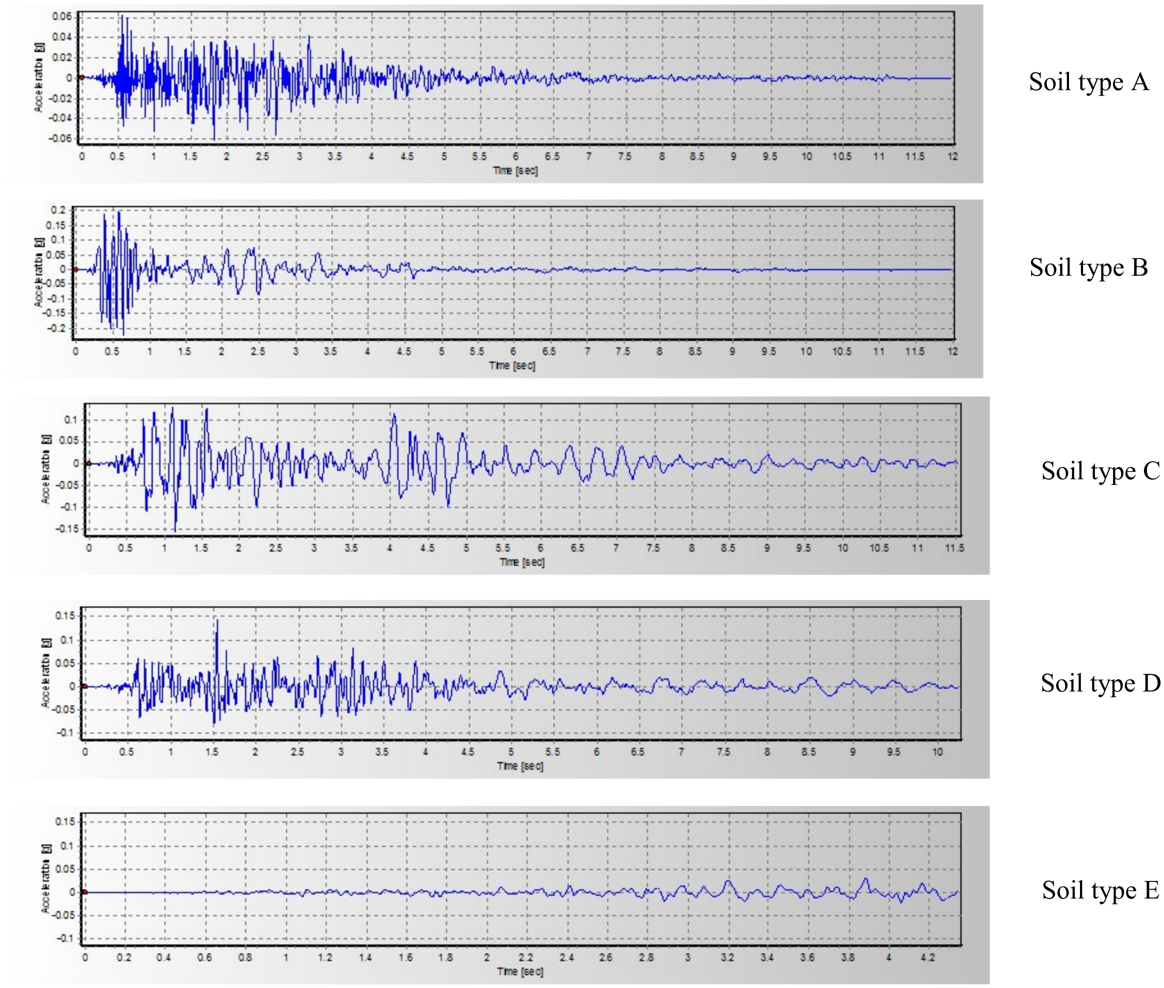


Figure 13. Recorded accelerograms of *Morgan Hill* earthquake (Morgan Hill 1984/04/24 21:15)

of each accelerogram has been drawn. All of accelerograms data are presented for different soils in Table 2 and Figure 9. Duzce earthquake spectrum is shown in Figure 10.

The second selected earthquake was Kocaeli earthquake (1999). The record of this earthquake has been registered on different soils and corresponding spectrum of each accelerogram has been drawn. All of accelerograms data are presented for different soils in Table 3 and Figure 11. Kocaeli earthquake spectrum is shown in Figure 12.

The third selected earthquake was Morgan Hill earthquake (1984). The record of this earthquake has been registered on different soils and corresponding spectrum of each accelerogram has been drawn. All of accelerograms data are presented for different soils in Table 4 and Figure 13. Morgan Hill earthquake spectrum is shown in Figure 14.

RESULTS AND DISCUSSION

Spectrum is a response of a structure with 1 degree freedom against different earthquakes. This means that created acceleration is specified in mass by applying recorded acceleration in past different earthquake to a system by one degree of freedom with different natural periods, on depending on soil structure. Modified cover of the acceleration is drawn in terms of natural periods for each type of soil structure. Sysmosygnal software was used for spectral analysis in this project. (Seismosoft, 2015). It is a useful application for processing the accelerograph data. Several spectrums are drawn as follows; acceleration spectrum, velocity,

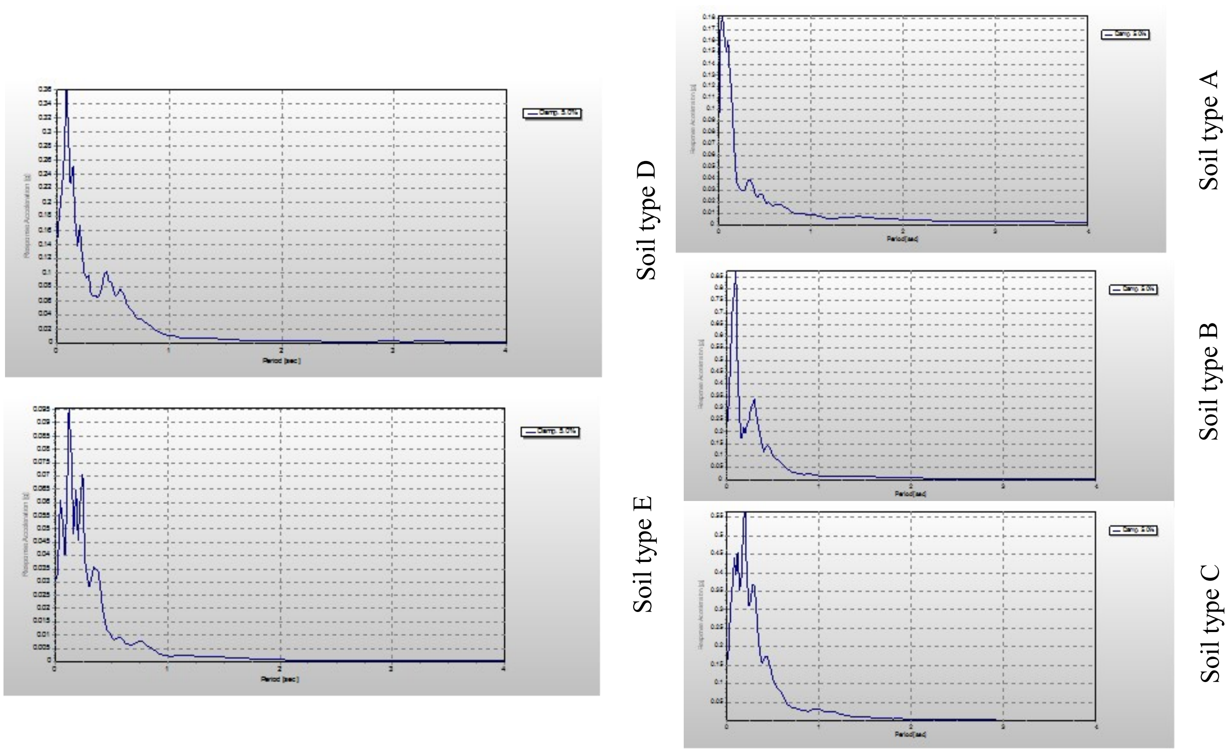
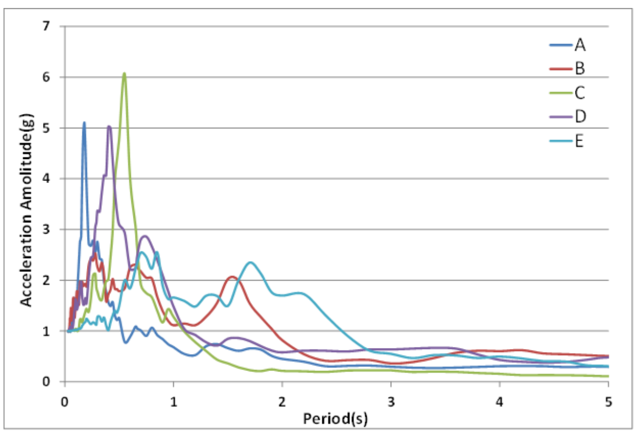
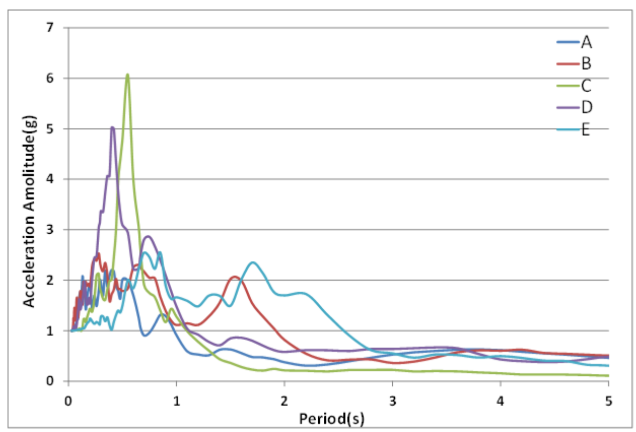


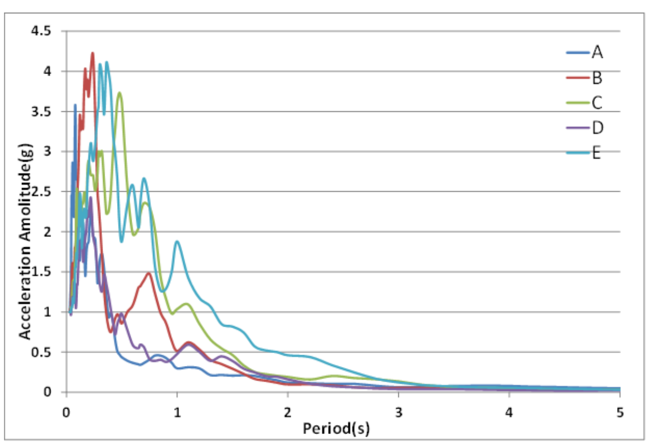
Figure 14. The spectrum of *Morgan Hill* earthquake (Morgan Hill 1984/04/24 21:15)



Duzce earthquake



Kocaeli earthquake



Morgan Hill earthquake

Figure 15. Spectrum earthquake of Studied accelerograms on different soils

Table 4. Recorded information of *Morgan Hill* earthquake (Morgan Hill 1984/04/24 21:15)

S. No	Site conditions	Distance (km)	Magnitude	Data source	Station	Soil type
1	Geomatrix or CWB (A)	Closest to fault rupture (16.2) Hypocentral() Closest to surface projection of rupture ()	M (6.2) Ml (6.2) Ms (6.1)	CDMG	Station: 47379 Gilroy Array #1	A
2	Geomatrix or CWB (B)	Closest to fault rupture (11.8) Hypocentral() Closest to surface projection of rupture ()	M (6.2) Ml (6.2) Ms (6.1)	CDMG	Station: 57383 Gilroy Array #6	B
3	Geomatrix or CWB (C)	Closest to fault rupture (3.4) Hypocentral() Closest to surface projection of rupture ()	M (6.2) Ml (6.2) Ms (6.1)	CDMG	Station: 57191 Halls Valley	C
4	Geomatrix or CWB (D)	Closest to fault rupture (15.1) Hypocentral() Closest to surface projection of rupture ()	M (6.2) Ml (6.2) Ms (6.1)	CDMG	Station: 47380 Gilroy Array #2	D
5	Geomatrix or CWB (E)	Closest to fault rupture (54.1) Hypocentral() .Closest to surface projection of rupture ()	M (6.2) Ml (6.2) Ms (6.1)	CDMG	Station: 58375 APEEL 1 - Redwood City	E

displacement, f*ourie* and other diagrams.

For each earthquake, the soil type impact on spectrum diagram is indicated by evaluating the results of the analysis on data derived from three mentioned earthquakes in the Figures of section five and also drawing the graphs of spectrum earthquake accelerograms for different soils on a chart (Figure 15). As can be seen, the domain of spectrum was higher because of increasing the hardness of soil in harez um similar desighn factor in low periods and the domain of spectrum was higher due to increasing the softness of soil in higher periods. And also in initial periods, the diagram is more gatherer and possess a greater amount in harder soil and the diagram is more extent and possess a lower amount in the softer soil.

CONCLUSION

It wouldn't generally be conducted that the harder soil is better or the softer soil is weaker, but a balance between soil and structure should be created according to the type of structure and frequency content. For example in short structure with softer soil, less force is applied to structures during earthquake and in high-rise structures with harder soil under the foundation, less force is applied to the structures. The force of earthquake reaches completely from bedder to ground in harder soil and there is a less possibility of creation plasticity in the soil but it contrary happens in soft soil. The force of earthquake quickly transfer the soil to plasticity stage and doesn't transfer the force completely.

- As can be seen in graphs; the domain of spectrum was higher due to the increasing hardness of soil in low periods and the domain of spectrum was higher due to increasing the softness of soil in higher periods.
- In general, and also in initial periods, the diagram is more gatherer and possess a greater amount in harder soil and the diagram is more extent and possess a lower amount in softer soil.

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