04 Apr 1995, 2:30 pm - 3:30 pm

The Amplification of Seismic Waves in Tehran

S. M. Mir Mohammad Hosseini

Amirkabir University of Technology, Tehran, Iran

Proceedings: Third International Conference on Recent Advances in Geotechnical Earthquake Engineering and Soil Dynamics,
April 2-7, 1995, Volume II, St. Louis, Missouri

The Amplification of Seismic Waves in Tehran

Paper No. 7.17

S.M. Mir Mohammad Hosseini
Assistant Professor of Civil Engineering Dept., Amirkabir University of Technology, Tehran, Iran

SYNOPSIS Vibrations of the bedrock due to earthquakes are transferred to the ground level via different soil layers. The arrived waves in the ground surface which affect the superstructures are usually stronger than those induced in the bedrock,depending on the geological and geotechnical characteristics of the soil layers.

In this paper the influence of different geotechnical parameters of a site on the amplification of earthquake waves are investigated using the mathematical equations of waves propagation in a visco-elastic half-space medium.A especial computer software was used to analyse the geotechnical data of a site in the western part of Tehran. The obtained results are illustrated as the response spectra in the ground surface to evaluate the effect of each parameter on the earthquake amplification. Finally the amplification factor of the site was calculated by comparing the bedrock and the ground accelerations obtained from the analysis.

INTRODUCTION

Induced motions in the bedrock during earthquakes are propagated to the upper layers in the form of stress waves. The arrived waves in the surface which are usually recorded by the accelerographs often differ considerably from those induced in the bedrock .Since superstructures are affected by these waves, studying the quantity and quality characteristics of the phenomenon, is of great importance.

Extensive studies have been carried out to obtain the effect of the geometric parameters of the sites on the amplification of earthquake waves,among which the works done by Dravinski,M.(1979),Tazoh,T.(1984), Ohtsaki(1987), Trifunac(1988), Lohn & heidi(1989) and Elgamal(1992) can be mentioned.

According to these investigations there is not a considerable effect of the geometric parameters while the waves length of the vibrations is very large compared with the site dimensions. The amplification also depends highly on the wave shape, wave mode or angle of radiations, soil layers and their thickness as well as the site topographic conditions. The response spectra of two points with the same conditions but different topography have the same frequency content but different amplitudes. Furthermore it can be concluded that the site geometric parameters has more considerable effect on the shear waves(s) than compression waves(p). The angle of natural slope and the dimensions of the mountains are some other important parameters in connection with the earthquake amplification. The effect of the geotechnical properties of the site on the amplification have been studied by many researchers among them Trifunac(1976), Seed & Idriss (1983), Singh(1989) and Lee & Hwang(1991) can be named.

Based on the results obtained by the above researchers, the alluvium layers located on the bedrock will amplify the acceleration spectrum but dissipate the high frequency waves. In soft soils the dominant site period depends only on the soil type but in medium dense soil the earthquake parameters such as epicentral distance, depth and the azimuth between the site and earthquake epicenter are also affecting the amplification. Among the geotechnical parameters the Secant shear modulus,plasticity index(for cohesive soils),density of the soil have the major effect and other parameters such as damping ratio and underground water table have a minor effect on the amplification

Since the above mentioned parameters have a great effect on the earthquake amplification and there are high amplifying potential in some part of Tehran(the capital of Iran), a special study has been carried out to investigate the quality and quantity of the amplification in a selected site in the western part of the city which is described in the following section.

THE SPECIFICATIONS OF THE SELECTED SITE

The selected site belongs to the Medical Science University of Iran which is located in the western part of the city and has an area of 14 hectares. The general slope of the site is about 6% from the north to the south and east to the west.

In figure 1 the position of the site and different boreholes are shown. According to the geotechnical investigations there are some loose layers of clay, sand and gravel near the surface. The soil layers become denser in further depths, so that the SPT numbers change from 20 near the surface to about 150 at the bottom of some boreholes in 15 meters depth.

The soil group in the unified soil classification system is mainly SC and CL.Hence its behavior highly depends on the water content. During Geotechnical

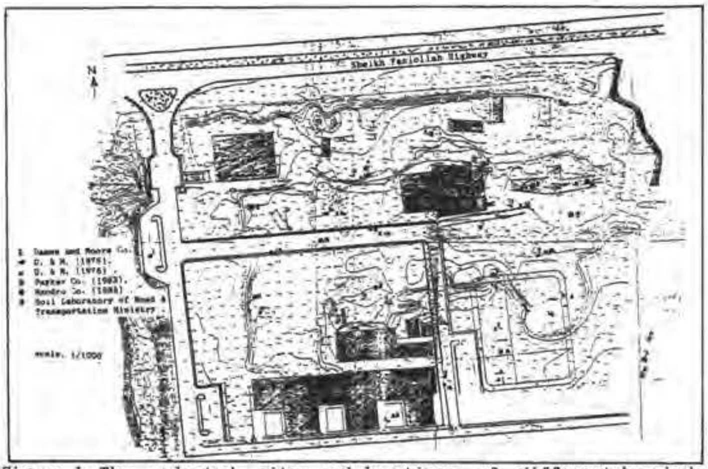

Figure 1- The selected site and locations of different boreholes.

investigations the water table was found in the depth of 60 meters which is not in the range of this study.

According to the geoseismic studies of the site by the microtremor method the dominant period of the site was obtained about 0.35 seconds(in the range of 0.2 to 1 seconds) which is quite reliable for the small motions. But it has to be modified for strong and large vibrations.

THE ANALYSIS METHOD

To analyse the response spectrum of the selected site during earthquake loadings a special one dimensional computer software called SHAKE was used. The software is based on the equation of the vertical propagation of the shear waves in a homogeneous and isotropic layered medium which is as bellow:

$$\rho \frac{\partial^2 u}{\partial t^2} = G \frac{\partial^2 u}{\partial x^2} + \eta \frac{\partial^3 u}{\partial x^2 \partial t}$$

in which :

ρ= the mass density of the medium

G= the shear modulus of the medium, and

η= the viscosity of the medium

In this model the soil is considered to behave linear visco-elastic.The geometry of the site can be modelled by a series of infinite horizontal and homogeneous soil layers (up to 20 layers) located on the halfspace elastic bedrock.

Although three dimensional models may lead to a more realistic results, but for the selected site which consists of different sedimental layers with small thickness and large dimensions the used model may lead to satisfactory results.

The limitation of the software in modelling only vertical shear waves may lead to more conservative results,because minimum reflection or maximum energy transmission will occur in this condition.

SELECTION THE APPROPRIATE ACCELEROGRAM

In order to use the analytical method mentioned earlier, the characteristics of the input earthquake is needed. The results of geoseismic studies of Tehran shows a great seismic potential of the city, nevertheless no strong earthquake has happened since the beginning of the current century. This may increase the risk of occurrence a heavy earthquake along many existing faults inside and around the city,specially the main and biggest one in the Mosha -Fasham district. Hence considering the high probability (64%), and return period of 100 years the magnitude of the most expected near field earthquake would be about M=7 Richter by horizontal acceleration of about 0.27g. For this reason the record of El-Centro earthquake(1948) by the maximum bedrock acceleration of 0.32g, duration of 15 sec. and dominant period of 0.5 sec. was used which is somewhat similar to the probable earthquake.

In order to correct and match the El-Centro accelerogram with the anticipated earthquake, it has been normalized for 0.27g as shown in figure 2. It can be also modified for other return periods and occurrence probabilities.

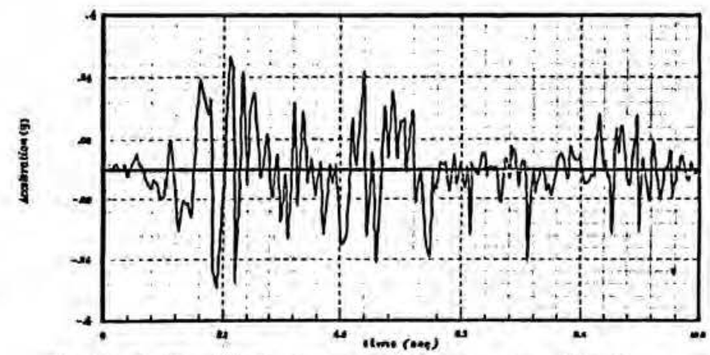

Figure 2- The El-Centro accelerogram normalized for 0.27g.

THE METHOD OF MODELLING THE SELECTED SITE

For modelling the site by the SHAKE program, the type, number and the thickness of soil layers on the bedrock, initial shear modulus(Go) or shear wave velocity(Vs), initial damping ratio and the density of each layer is required.

According to geotechnical investigations it was found that three parallel layers form the site on the bedrock. The density of the layers increases as going to the depth.Also the water table is very deep and the soil layers are not saturated in the zone of studies.

Since the shear modulus of the layers were not measured during geotechnical investigations, the shear wave velocity was used instead.For determining this parameter beside using the geoseismic results, the correlation between SPT and Vs has also been used.The average values of different parameters used in modelling the site are presented in table I.

TABLE I. Parameters used in modelling the site

number of layers	thickness (m)	SPT (N)	density (t/m^3)	Vs (m/sec.)
1	4.9	50	1.50	305
2	9.8	100	1.76	381
3	35	150	1.96	457
4	bedrock	>200	2.00	503

According to the results of studies carried out by Tehran Underground Company, the damping ratio for all layers was taken to 5%, which is in good agreement with the viscoelastic behavior of the soil under small strains and is used in many local studies.

THE RESULTS OF STUDIES

The results of studies for the selected site are shown in figures 3 to 8. In these figures variations of the response spectrum of the ground accelerations versus different parameters are plotted. The effect of the density, shear waves'velocity, damping ratio, thickness of layers, and finally the bedrock depth on the response spectrum are evaluated and illustrated.

It can be seen from figure 3 that the density of the alluvium only changes the amplitude of the response spectrum without affecting the frequency content or the site dominant period. Also it is apparent that variations of the density of the second and third layers lead to similar results. However the effect of the density on the upper layers is more than the lower ones.

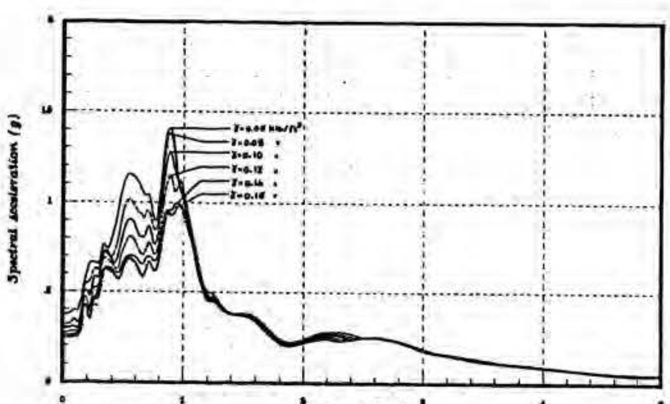

Figure 3- The ground response spectra for different densities.

From figure 4 it is evident that the effect of shear wave velocity or shear modulus on the response spectrum of the layers is almost negligible. The effect of variations of the bedrock shear modulus on the response spectrum is shown in figure 5. As it can be seen this variation does not affect the response spectrum in the range of dominant frequency, but increases the acceleration amplitude up to 100%.

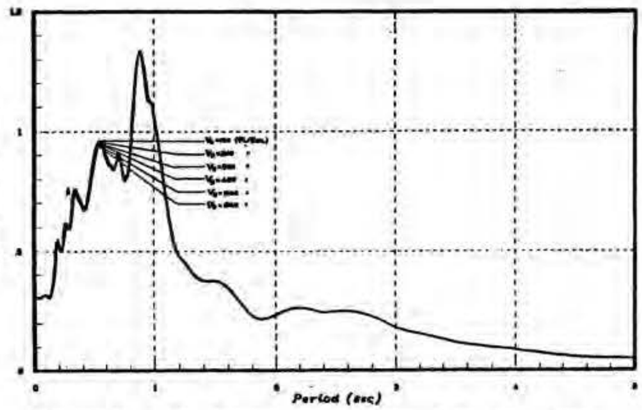

Figure 4- The ground response spectra for different shear wave velocities.

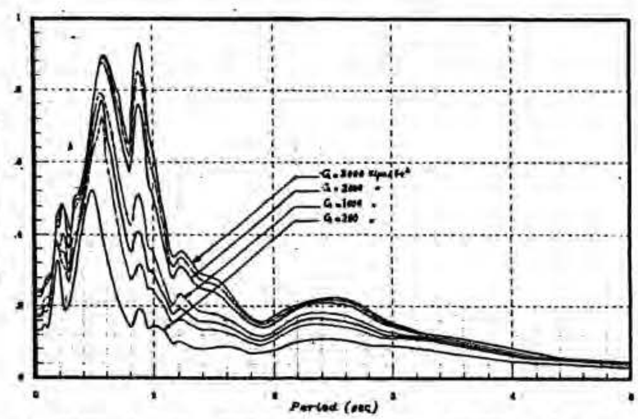

Figure 5- The ground response spectra for different shear moduli.

Although the damping ratio of 5% is a reasonable value in the range of small strains for this analysis, but for more investigations, four other ratios from 1 to7% were tried to study the influence of damping ratio on the response spectrum. As it is shown in figure 6, the damping ratio does not affect the response spectrum in the range of dominant period and only changes the amplitude of the maximum acceleration. It is evident that for damping ratio of 1% the maximum acceleration increases to about 2.32g, while for the ratio of 7% it becomes 1.1g.

Since the thickness of the first layer under the structure has the major effect on the ground vibrations, in this study, the thickness of the first layer (which is about 5m in the selected site) has been altered from 2 to 10m(6 to about 30 ft.). As it can be seen from figure 7, icreasing the thickness of the first layer will decrease the amplitude of the acceleration but increase the dominant period of the site. It is evident that changing the thickness from 6 to 30 feet will decrease the maximum acceleration from 1.38g to 0.9g, a reduction of about 50%. The changing of the lower layer thickness will lead to a similar result but with smaller variations.

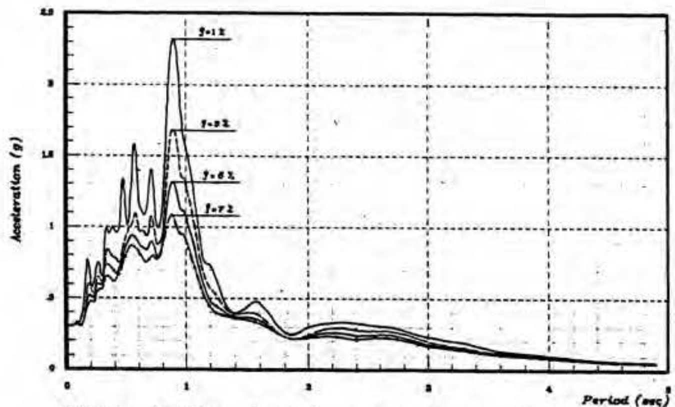

Figure 6- The ground response spectra for different damping ratio ratios.

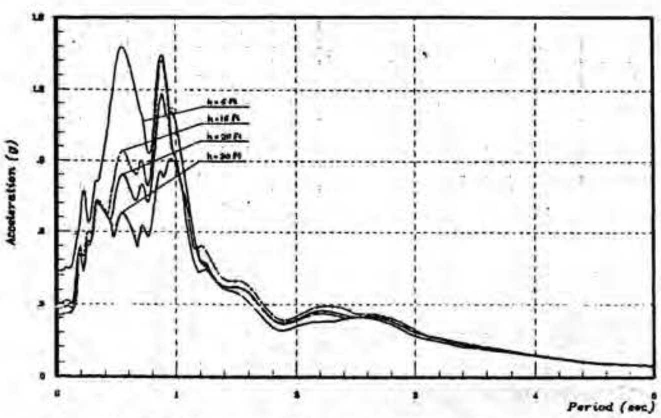

Figure 7- The ground response spectra for different thickness of the first layer.

Finally the acceleration response spectrum of the site in the bedrock and ground level have been illustrated in figure 8. As it can be seen not only the frequency content changes due to geotechnical characteristics of the soil layers, but the amplitude of the maximum acceleration increases over 70%.

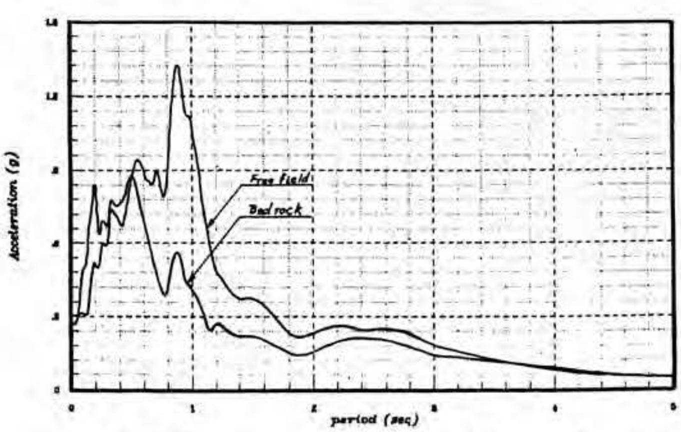

Figure 8- Response spectra of the acceleration in the bedrock and ground level for the

SUMMARY AND CONCLUSIONS

The earthquake amplification of the Tehran alluvium in a selected site of 14 hectares has been investigated. Having several geoseismic and geotechnical data of the site, the influence of different parameters on the amplification was investigated.

According the obtained results, while the density of the soil layers on the bedrock has no effect on the dominant period of the site, it would decrease the amplitude of the acceleration. An increase to shear modulus will increase the acceleration amplitude considerably, without any influence on the frequency of the response spectrum.

The damping ratio of the soil also has no effect on the dominant period of the response spectrum, but changes the acceleration amplitude sharply. Increasing the damping ratio of about 6% will result in more than 200% decrease in the amplitude of the maximum acceleration at the ground level. Also increasing the thickness of the first layer decreases the amplitude of the ground acceleration, while increases the dominant period of the site Finally, increasing the depth of the bedrock or the total thickness of the soil layers only changes the amplitude of the ground acceleration without affecting the site frequency content.

REFERENCES

Dravinski, M. (1989), " Ground Motion Amplification due to Elastic inclusions in Half-Space", E.E.S.D , Vol. 18, PP.903-919.

Elgamal, A.W. (1992), " Three Dimensional Seismic Analysis of Lavillita Dam", J.G.E.,Vol.118, No.12 P.1937.

Hwang, H.E.& Lee, C.(1991), " Parametric Response of Site Response Analysis", S.D.E.E., Vol.10, No.6, P.282.

Lohn & Heidi, (1989), " The Effect of Topography on the Amplification of Seismic Waves",U.M.I.Thesis..

Ohtsuki & Harumi, (1987), " Effect of Topography and subsurface on Seismic SV Waves",E.E.S.D.,Vol.1 No.4, P.441.

Pak, A. & Jafari, M.K. & Mir Hosseini, S.M., (1993), " The Analytical Investigation of the Seismic Waves Amplification in the Alluviums and Its local Application for the city of Tehran", M.Sc. Thesis Amirkabir University of Technology, Tehran, Iran.

Seed, H.B. & Idriss, I.M. (1970), " Soil Moduli and Damping for Dynamic Response Analysis", E.E.R.C., Report No.70-10 Berkely.

Tazoh, T.,(1984), " Effect of Lateral Inhemogeneity on Seismic Waves", E.E.S.D., Vol.12, P.792.

Trifunac & Moeenvaziri, (1988), " Scattering and Diffraction of Plane Waves", S.D.E.E., Vol.7, No.4 P.178.