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INFLUENCE OF EFFECTIVE DURATION OF STRONG MOTION ON ELASTIC RESPONSE SPECTRA

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SUMMARY

In this paper the influence of effective duration of strong motion, soil condition, magnitude and shape of accelerogram time history on elastic response spectra have been investigated. A total of 108 Iran's horizontal acceleration components strong motion records are selected. These accelerograms are catagorized in accordance with their earthquake parameters and soil condition of recording station and the influence of different conditions are plotted in graphs. In all cases the response spectra have been calculated for a structure with a damping ratio of 5%. Analytical results show that the influence of soil condition is very significant on the shape of response spectra. The influence of effective duration of strong motion, has been studied by definition based on energy of accelerogram. It can be seen that an increase in effective duration, causes reduction in the slope of response spectra in long period part and increases the spectral values.

INTRODUCTION

Response spectrum is the most suitable tool developed so far for expressing the excitation response relationship in earthquake engineering and seismic design. Although it is an indirect measure of ground motion intensity, it expresses maximum response directly which is a major concern in design.

If one generates sets of response spectrum curves for ground motions recorded at different locations during past earthquakes, large variation will be observed in both the response spectral values and the shape of the spectrum curves from on set to another. These variations depend upon many factors such as energy release mechanism in the vicinity of the focus or hypocenter and along fault interfaces, epicentral distance and focal depth, geology and variations in geology along energy transmission paths, Richter magnitude and local soil conditons at the recording station. Thus the response spectral values S (Spv, Spa and Sd) for earthquake ground motion should be thought of in the form [Clough and Penzien, 1993]

$$S = S(SM, ED, FD, GC, M, SC, \xi, T) \tag{1}$$

where the independent variables denote source mechanism, epicentral distance, focal depth, geological conditions, Richter magnitude, soil conditions, damping ratio and period, respectively. The effects of SM and GC on both spectral values and shapes of the response spectrum curves are not well understood; therefor such effects can not be quantified when defining response spectra for design purposes. The effects of ED, FD and M are usually taken into consideration when specifying the intensity levels of the design response spectra; however, they are often ignored when specifying the shape of these spectra because of lack of knowledge as to their influences. On the other hand the effects of SC on both the intensities and shapes of response spectra are now being considered widely when defining design response spectra.

In addition to plotting response spectra on tripartite (four way logarithmic) scales for Sd, $Spv = \omega Sd$ and $Spa = \omega 2\ Sd$, it is sometimes convenient to plot the ratio of the response to the appropriate ground motion (amplification). In many cases the ratio of spectral acceleration to peak ground acceleration (acceleration amplification) is plotted as a function of either frequency or period.

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In this study the effect of soil condition and magnitude on response spectra is considered. In addition to these parameters, the effect of time duration of strong motion is evaluated. The time duration of strong motion for earthquakes is calculated from the definition of Trifunac and Brady [1975] and is pointed out in reference [Tehranizadeh and Hamedi, 1999]. For evaluating the effect of shape of accelerogram's time history, the records are grouped in accordance to their peak ground accelerations (PGA) and the influence of this parameter is shown.

In this study 108 Iran's earthquakes strong motion records are used. These accelerograms are selected from the "Basic Accelerograms Data of the Iranian Accelerographs Network" [Ramazi, 1997]. In this selection only the records which their soil conditions have been determined by geophysical (geoseismical and geoelectrical) observations are chosen (type A). These data are seismically proccessed and longitudinal and transverse components with maximum ground accelerations greater than 50 gal are used.

EFFECT OF TIME DURATION OF STRONG MOTION ON RESPONSE SPECTRA

The records are divided in 5 groups for this evaluation. The time duration of strong motion is the time interval which is between 5% to 95% of total accelerogram energy takes place. This time is pointed out in [Tehranizadeh and Hamedi 1999] for these number of selected records. The time duration is between 0.18 to 39.24 seconds for these records and the records are grouped as:

Type (a): time duration between 0 to 2 seconds; 24 records

Type (b): time duration between 2 to 4 seconds; 25 records

Type (c): time duration between 4 to 6 seconds; 18 records

Type (d): time duration between 6 to 10 seconds; 23 records

Type (e): time duration longer than 10 seconds; 18 records

In Figure 1 average and mean plus one standard deviation values for first group, it means with time duration between 0 to 2 sec, are plotted. In this diagram the logaritms of pseudo velocity Spv is drawn with the logaritms of the structure's period. Curve (a) shows the average spectral values (50 percentile) and curve (b) shows the mean plus one standard deviation (84.1 percentile). The shpae of spectra is very sharp with a maximum at period 0.2 second. For smaller periods the two curve are very close together and for longer periods their difference increases. This Figure shows that structures with period near 0.2 seconds (two-storey structures) are very sensitive to earthquakes with short time durations.

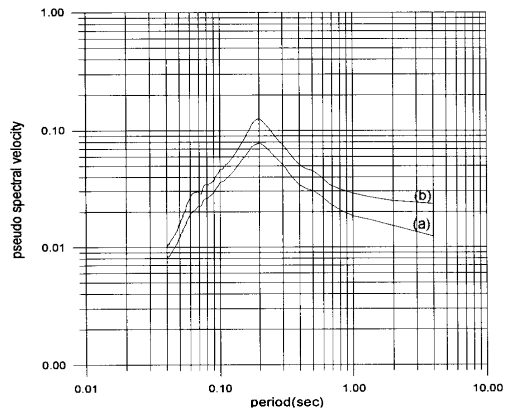

Figure 1: Average and mean plus one standard deviation for earthquakes with 0 to 2 second duration

Figure 2 shows the average and Figure 3 shows the mean plus one standard deviation for all five group of time durations. Curves (a) to (e) shows each group repectively. Curves (a) to (d) have a maximum at period 0.2 second but the curves (b) to (d) have smaller slopes and are flatter than curve (a). When the time duration of strong motion increases and is longer than 10 seconds, the maximum is on the period of nearly 1.0 seconds, so the short structures (nearly 2-storey) are sensitive to earthquakes which their time duration of strong motion is shorter than 10 seconds and medium to tall structures (nearly 10-storey) are sensetive to earthquakes with time duration longer than 10 sec. In Iranian code for design of structure for seismic loadings, it has been noted that for time history analysis of structures, the designer must use the records of earthquakes with time duration of strong motions longer than 10 seconds. This would be some what under design for small structures and very over-estimate for medium to tall structures.

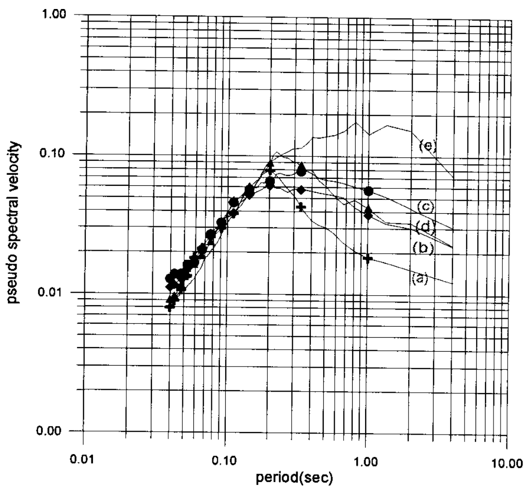

Figure 2: Average of five group of earthquakes with different time duration

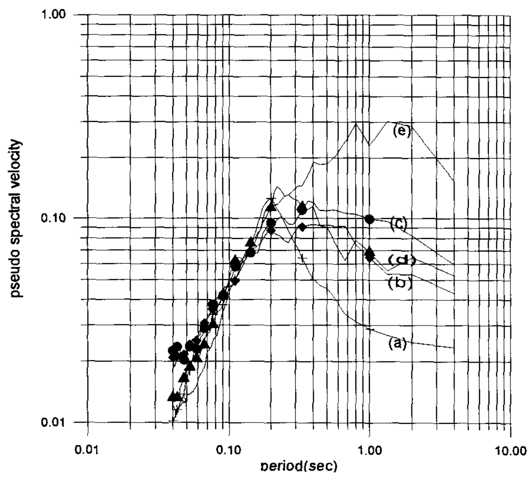

Figure 3: Mean plus one standard deviation for five goup of earthquakes with different time duration

The influence of duration of strong motion on response spectra has been studied by Peng et al., [1989] who compared acceleration amplifications for earthquakes with 5, 10 and 20 seconds duration with that of SEAOC and showed that a longer duration of strong motion increases the response in the low and intermediate frequency regions. This is consistent with the fact that accelerograms with long duration of strong motion have a greater propability of containing long period waves which can result in a higher response in the long-period (low frequency) region of the spectrum [Mohraz and Elghadamsi, 1989].

EFFECT OF SOIL CONDITION ON RESPONSE SPECTRA

Prior to the San Fernando earthquake of 1971, accelerograms from pervious earthquakes were limited in number, and the majority were recorded on alluvium [Mohraz and Elghadamsi 1989]. But after that many researchers work on the influence of soil condition on response and design spectra. Seed et al., [1976] and Mohraz [1976] have curves which show the effect of different soil types on acceleration amplification. In the study by seed a total of 104 horizontal component of earthquake records have been used and they show that the average value of acceleration amplification for a soil type like soil type No II of Iranian code would have the maximum value of 2.9 . For softer soils the curves whould be flatter and for periods greater than approximately 0.4-0.5 seconds, the acceleration amplification for rock are substantially below those for soft to medium clay and for deep cohesionless soil, so using the spectra from the latter two groups may overestimate the design amplifications for rock.

In this study the records are divided in accordance with the station soil type. This classification is on the basis of Iranian code of practice for seismic resistant design of buildings. According to Iranian code four different groups of soil are defined as follow:

I: rock and very stiff soil (Vs > 750 m/s)

II: Stiff soil (375 < Vs< 750)

III: soft soil (175 < Vs < 375)

IV: very soft soil (Vs < 175 m/s)

With these soil types there are 51 records on type I , 36 records on type II , 10 records on type III and 11 records on type IV.

Figure 4 shows the effect of soil condition on response spectra. This figure shows the pseudovelocity for earthquakes with time durations longer than 10 seconds. For softer soil the spectral values increases for structures with periods greater than 0.2 seconds, but for other structures, short buildings, the soil condition have no substaintial effect on the response spectra.

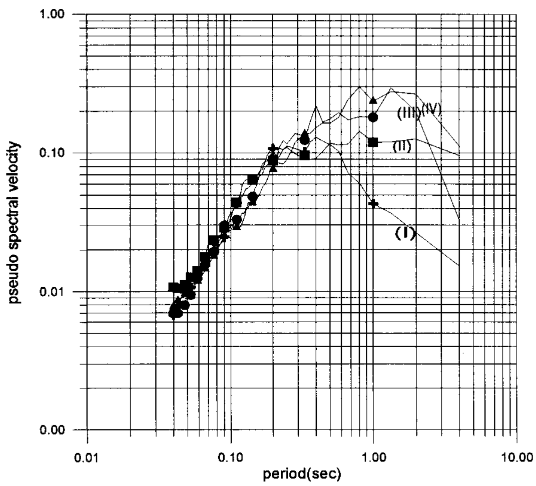

Figure 4: Effect of soil condition for earthquakes with time duration of strong motion longer than 10 seconds.

Figure 5 shows the effect of soil condition on response spectra for all of the records. The average of spectral acceleration for four soil groups are shown. As can be seen from the figure the response spectra for soil type I has a maximum of 2.8 at a period of nearly 0.2 second and the curve has great slopes on both sides of this point. For soil type II the slopes are as for type I, but a maximum of 2.55. It means that acceleration is smaller for type II than type I. (In contrast with that of Seed et all,.). Soil types III and IV have similar slope for periods smaller than 0.2. The maximum of curve in this case is 2.5. For large periods (nearly 4 seconds) all the four soil types have nearly equal values.

Figure 6 shows the mean plus one standard deviation of spectral acceleration for each soil groups. Comparing with figure 5 it has greater spectral values which reaches 4.0 for soil type I , and this is more than the spectral values for other regions than Iran. The variation of acceleration and spectral curve shape is like figure 5 which is

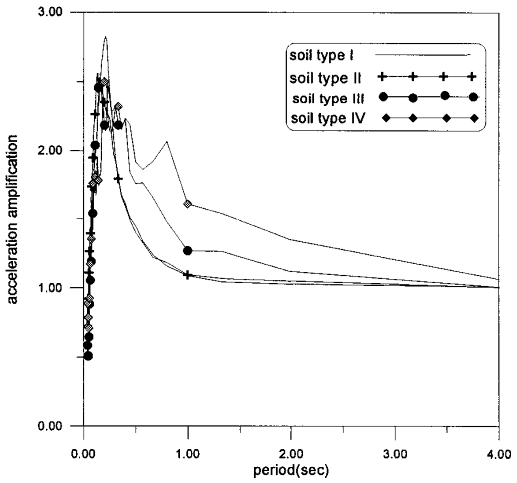

Figure 5: Average acceleration spectra for all soil types.

drawn for 50 percentile. For softer soils either the maximum value or the slope of curve for periods longer than 0.2 seconds decreases, therefor the acceleration amplification is greater for soft soils than stiff soils in periods between 0.2 and 4.0. Soil types I and II shows nearly equal values in this region.

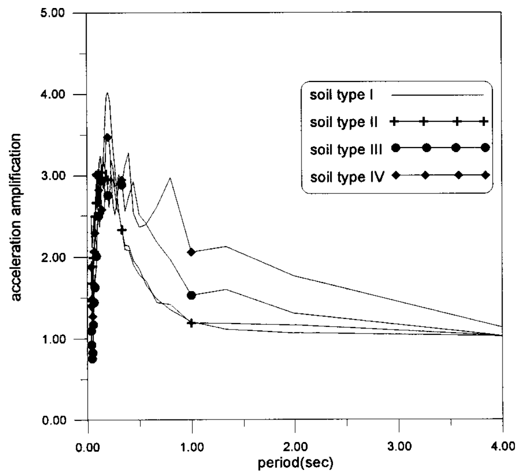

Figure 6: Mean plus one standard deviation acceleration spectra for all soil types

EFFECT OF EARTHQUAKE MAGNITUDE ON RESPONSE SPECTRA

The earthquake magnitude influence the response spectral shape and values. A study by Mohraz [1978] on the influence of earthquake magnitude on response amplification for alluvium shows larger acceleration amplifications for records with magnitude between 6 and 7 than for those with magnitudes between 5 and 6. They show that this effect may need to be considered when developing design spectra for a specific site, particularly for critical structures.

In this study the records are grouped in accordance to their magnitude. 15 records have magnitude smaller than 4, 49 records have magnitude between 4 and 5, 22 records are between 5 and 6; and finally 16 records with magnitude greater than 6. So four groups are specified. Figure 7 shows the effect of magnitude on response spectra for these four groups. For high frequency structures, the acceleration amplification decreases with an increase in earthquake magnitude so for structures with periods smaller than 4.0 gives greater acceleration amplification but medium and high rise structures are more sensitive to earthquake with high magnitude specially with magnitudes over 6.

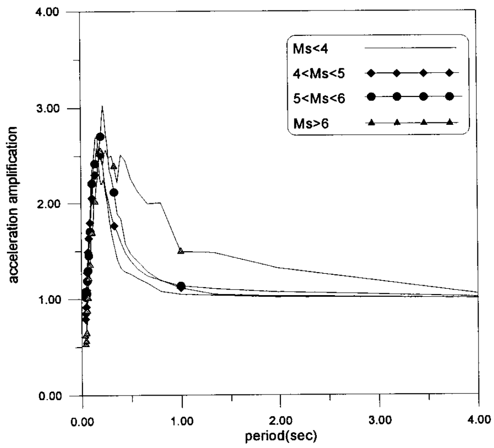

Figure 7: Average acceleration spectra for different earthquake magnitudes

EFFECT OF ACCELEROGRAM SHAPE ON RESPONSE SPECTRA

In order to show the effect of accelerogram shape on response spectra the records are grouped on the basis of their PGA. It is noted that each accelerograms ordinate is divided to the PGA of that accelerogram before calculating the response spectra, so the accelerograms are normalized and the response spectras are for a unit acceleration. So the results of this study is not applicable to spectra values but the spectral shape. In this study the records are grouped in 10 groups as follow:

$50 \leq PGA < 60 \rightarrow$14 records

$60 \leq PGA < 70 \rightarrow$12 records

$70 \leq PGA < 80 \rightarrow$15 records

$80 \leq PGA < 90 \rightarrow$8 records

$90 \leq PGA < 100 \rightarrow$10 records

$100 \leq PGA < 150 \rightarrow$11 records

$150 \leq PGA < 200 \rightarrow$10 records

$200 \leq PGA < 250 \rightarrow$8 records

$250 \leq PGA < 300 \rightarrow$9 records

$PGA \geq 300 \rightarrow$11 records

Figure 8 shows the effect of these 10 groupes. The figure shows that spectral values are very close to each other and all curves have a maximum at a period nearly 0.2 second which is from 2.2 for earthquakes between 80 and 90 gal to 3.4 for earthquakes between 90 and 100 gal. The shape of all curves are similare and shows that the shape of accelerogram time history has no significant effect on response spectra

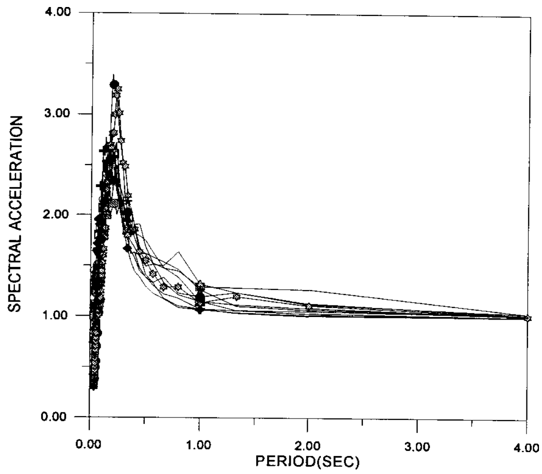

Figure 8: Effect of acceleregram time history on response spectra

CONCLUSION

1. An increase in time duration of strong motion causes the response spectra to be flatter and have smaller slope, so for most periods an increase in time duration causes greater spectral values.

2. The spectral shape is very sharp for average (50 percentile) value for soil type I and have a maximum of 2.8 at period 0.2 seconds. For softer soils the spectral curve is flatter and have a maximum of 2.5.

3. The 84.1 percentile mean plus one standard deviation curve has a maximum value nearly 4.0 for soil type I.

4. For low-rise structures the earthquakes with small magnitude are important but for medium to high-rise structures that have periods greater than 0.3 , high magnitude earthquakes control the response spectra.

5. The earthquake time history has no significant effect on respons spectra.

REFERENCES

Clough, R. and Penzien, J. (1993) , “Dynamics of structures”, MC Graw Hill Inc.

Mohraz, B. (1976) , “A study of earthquake response spectra for different geological conditions”, Bull. Seism. Soc. Am. 66, No. 3, 915-935

Mohraz, B. (1978) , “Influences of the magnitude of the earthquake and the duration of strong motion on earthquake response spectra”, Proc. Central Am. Conf. on earthquake Eng. San Salvadore

Mohraz, B. and Elghadamsi, F. E. (1989), The seismic design handbook , Van Nostrand Reinhold , Newyork p32-80

Peng, M. H., Elghadamsi, F. E. and Mohraz, B. (1989), “A simple procedure for constructing probabilitic response spectra”, Earthquake Spectra, Vol. 5, No. 2

Ramazi, H. R. , (1997) “Basic accelerograms data of the Iranian accelerographs network”, building and housing research center, No. 256 in Farsi

Seed, H. B., Ugas, C. and Lysmer, J. (1976) , “Site-dependent spectra for earthquake-resistance design”, Bull. Seism. Soc. Am. 66, No.1, 221-243,

Tehranizadeh, M and Hamedi, F. (1999) , “Effect of earthquake source parameteres on Iran’s earthquake duration”, Proc of third Intl. Conf. on Seismology and Earthquake Engineering (SEE3),Tehran , Iran.

9 Trifunac, M.D. and Brady, A. G. (1975) “A study of the duration of strong earthquake ground motion”, Bull. Seism. Soc. Am. 65. 581-626,