13th World Conference on Earthquake Engineering
Vancouver, B.C., Canada
August 1-6, 2004
Paper No. 2729

EFFECTS OF SOIL LAYER CONSTRUCTION ON CHARACTERISTIC PERIODS OF RESPONSE SPECTRA

BO Jing-Shan[1], LI Xiu-Ling[2], LIU Hong-Shuai[3], WU Zhao-Ying[4], LIU De-Dong[5]

SUMMARY

In this paper, some representative site profiles with engineering significance are selected and constructed, and ground surface acceleration peaks(GSAP) and velocity peaks(GSVP) of different site profiles under various input ground motions are calculated using 1-D equivalent linearization wave method employed widely for seismic response of sites. GSAPs and GSVPs obtained are used to calculate the response spectra characteristic periods (T_g) of different sites under various input ground motions. Effects of soil layer construction on T_g s of response spectra are studied, and some valuable results are obtained.

INTRODUCTION

It is well known that characteristic period(T_g) of response spectra is one of the most parameters of calibrated seismic design response spectra and also an important parameter to study frequency spectrum of ground motion produced by earthquake. When T_g s of design spectra were determined, the influences of site categories and design ground motion groups were concerned, and yet the effects of soil layer construction on T_g s of design spectra were not considered[1] in Chinese current Code of Seismic Design of Buildings. Both observations of strong earthquake and engineering practice indicate that there are significant differences of T_g s of acceleration response spectra of the sites which are classified into the same site category and yet with different soil layer construction, so it is quite important to study the effects of soil construction on T_g s of response spectra for reasonably determining seismic design spectra.

[1] Professor, Institute of Engineering Mechanics, China Earthquake Administration.
Email: jingshan@mail.hl.cn
[2] Graduate Student, Dalian University of Technology, China. Email: lxl-138@sohu.com
[3] Graduate Student, Institute of Engineering Mechanics, China Earthquake Administration.
Email: liu_hs@sina.com
[4] Graduate Student, Earthquake Administration of Jilin Province, China. Email: wzy_iem@yahoo.com
[5] Engineer, Institute of Engineering Mechanics, China Earthquake Administration. Email: ldd-35@163.net

T_g s of ground surface acceleration response spectra of various soil layer construction are calculated, and then the effects of various soil layer thicknesses, soft soil layers on T_g s of surface acceleration response spectra are studied. The results obtained in this paper have a certain value on further studying site classifications and so on.

SELECTION OF COMPUTATIONAL METHOD

At present, 1-D equivalent linearization wave method in frequency domain is usually used to analyze seismic response of ground layered soil layers in engineering practice [2, 3]. This method, recommended by Chinese National Standard-Code for Seismic Safety Evaluation of Engineering Sites(GB17741-1999), is employed to calculate ground surface acceleration peaks- $A_{\max}$ and velocity peaks - $V_{\max}$ of site profiles. Surface acceleration peaks- $A_{\max}$ and velocity peaks- $V_{\max}$ of different site profiles under various input ground motions are computed; T_g s of design response spectra are determined using two-factor approach [4]; and the results of calculation are analyzed to study effects of soil layer construction on T_g s of response spectra.

CONFIRMATION OF COMPUTATIONAL PROFILES AND PARAMETERS

According to the requirements of computational profiles and parameters in 1-D equivalent linearization wave method of ground layered soil, 21 basic site profiles for calculation, based on hundreds of bores of engineering sites in China, are selected and constructed. The thicknesses of overlying layer of these profiles rang from 3 to 100 m, shear wave velocities and densities of each layer soil, referred to measured data in-situ, are given with considering engineering geological characters of sites. Dynamic shear modulus ratios and damping ratios of soils, recommended by Yuan (2001) [5], are mainly employed, and others are derived from experimental data. To avoid effects of frequency spectrum, while considering earthquake shaking, ground motion acceleration time history with a peak of 0.4 g, as shown in figure 1, is called C

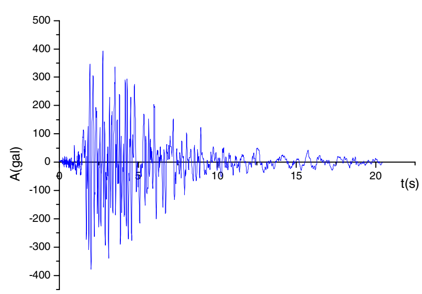


Figure 1 acceleration input ground motion(C time history)

time history. C time history is scaled to 0.2 g for use as B time history and to 0.1 g for use as A time history. Soft soil layer in the paper is the soil layer whose shear velocity is less than 140 m/s, and is the least. The basic profiles selected and constructed in the paper are mainly from [6].

ANALYSIS OF COMPUTATIONAL RESULTS

Effects of thicknesses of overlying layer on T_g s

To study the effects of thicknesses of overlying layers on T_g s, T_g s of 21 site profiles, whose thicknesses of overlying layer are 3, 5, 10, 15, 20, 25, 30, 35, 40, 45, 50, 55, 60, 65, 70,75, 80, 85, 90, 95 and 100m respectively, are calculated using 1-D equivalent linearization wave method of ground layer soil, and T_g s of different site profiles under various input ground motions are presented in Figure 2. In Figure 2, abscissa-H means thickness of overlying layer, whose unit is meter, and ordinate-T_g means characteristic

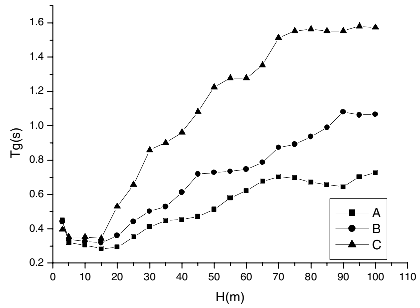


Figure 2 the effects of overlying layer's thicknesses on T_g s

period of response spectra, whose unit is second. Curve A, B and C represent the outcome of input ground motion A, B and C, respectively. Figure 2 shows that T_g of acceleration response spectra increases with increasing H , that to the same H, T_g increases with increasing intensity of input ground motion, and that if H is no more than 15m, the variation of T_g is little.

Effects of soft surface layer on T_g s

Soft soil has special engineering characters. Earthquake damage indicates that soft soil has significant effects on earthquake damage. As to profiles with soft soil on the top, two cases are studied as follows:
(1) the thickness of soft soil layer doesn't change, while the thickness of overlying layer changes; and
(2) the thickness of overlying layer doesn't change, while the thickness of soft layer changes.

As to the first case, the surface layers of 21 selected and constructed site profiles without soft layer(called as "normal profiles") are replaced with soft layer, whose velocity and density are 107 m/s, 1.58 ton/m^3, and then new profiles are formed. T_g s of these normal and new profiles under various input ground motions are computed using the above method in section 2, and are compared, as shown in Figure 3. In

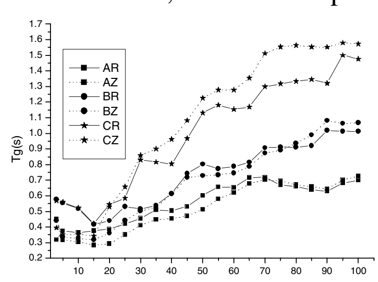


Figure 3 the effects of soft surface layer on T_g s under different H

Figure 3, real line AR, BR and CR represent the outcome of profiles with soft layer under input ground motion A, B and C, respectively, while dotted line AZ, BZ and CZ represent the outcome of normal profiles without soft surface layer under input ground motion A, B and C, respectively. The obtained results show that on the whole T_g s of profile with soft surface layer are bigger than the values of normal profiles and T_g increases with increasing thickness of overlying layer. Compared to normal profiles, the three pieces of learning are gained:

(1) If intensity of input ground motion (peak is 0.1g or 0.2g) is small, T_g s of profiles containing soft surface layer are bigger than the values of normal profiles when the thickness of overlying layer is less than 70 meters, and T_g s of profiles containing soft surface layer are smaller than the values of normal profiles when the thickness of overlying layer is more than 70 meters;

(2) If peak of input ground motions is 0.4 g, T_g s of profiles containing soft surface layer are smaller than the values of normal profiles;

(3) If the thickness of overlying layer-H is less than 15 m, the variation of T_g is smaller under A time-history than that under B and C time-history.

As to the second case, three profiles with the thicknesses of 20m, 40m, 60m, respectively, are selected. For the profile whose thickness of overlying layer is 20 m, 7 new profiles are formed by changing the thickness of soft surface layer in profiles, from 2 to 5 m; for the profile whose thickness of overlying layer is 40m, 9 new profiles are formed by changing the thickness of soft surface layer in profiles, from 2 to 9 m; for the profile whose thickness of overlying layer is 60m, 12 new profiles are formed by changing the thickness of soft surface layer in profiles, from 2 to 25m. T_g s of response spectra of these new profiles under different input ground motions are calculated using the method stated in section 2, as shown in Figure 4. In figure 4, Hr means thickness of soft surface layer. Figure 4 indicates the relationship between the thicknesses of soft surface layer and T_g s of different profiles under various input ground motions.

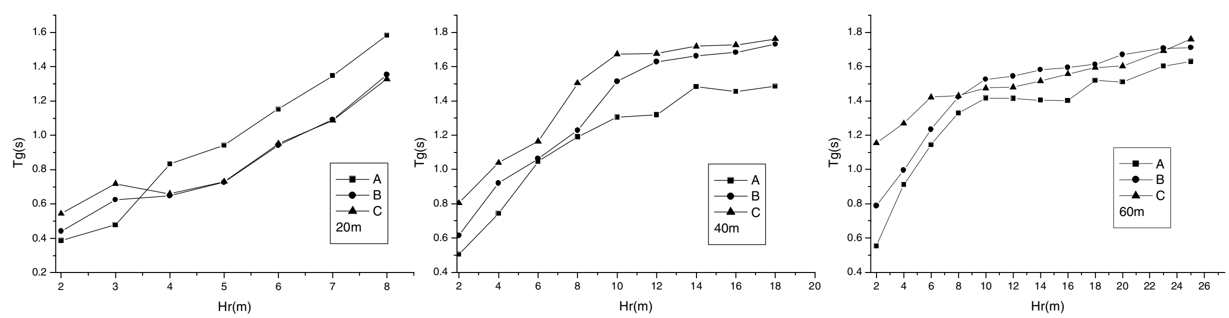


Figure 4 the effects of thicknesses of soft surface layer on T_g s

Figure 4 indicates that T_g increases with increasing the thickness of soft surface layer. If soft surface layer thickness is smaller, T_g increases with increasing the intensity of ground motion; while if the thickness of soft surface layer is bigger, the relationship between T_g and the intensity of ground motion is complex.

Effects of soft bottom layer on T_g s

Some profiles (thicknesses of overlying layer ranging from 5 to 70m) are selected, at the bottom of which soft layers are placed. T_g s of these new profiles and normal profiles under different input ground motions are calculated, as shown in Figure 5. ARD, BRD and CRD in Figure 5 represent the outcomes of the profiles containing soft bottom layer under A,B and C time history, respectively, while AZ, BZ and CZ in

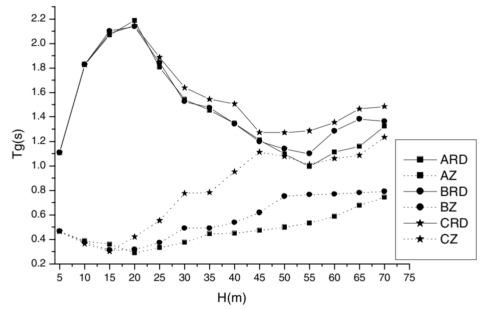


Figure 5 the effects of soft bottom layer on T_g s

Figure 5 represent the outcome of normal profiles without soft bottom layer (normal profiles) under A, B and C time history, respectively. Figure 5 indicates that T_g s of profiles with soft bottom layer are big compare to the values of normal profiles. In the case of existing soft bottom layer, if H is less than 20m, T_g increases with increasing thickness of overlying layer, and if H is more than 20m, T_g decreases on the whole with increasing H.

Effects of soft interlayer on T_g s

The effects of imbedded depths of soft interlayer and thicknesses of soft interlayer at different depths on T_g are studied.

At First, to study the effects of imbedded depths of soft interlayer on T_g s, two profiles with the thicknesses of overlying layer of 50 and 70m, respectively, are selected, and several new profiles are formed by replacing layers at different depths with soft layer. T_g s of the new profiles are calculated using the method stated in section 2, as shown in Figure 6. In Figure 6, abscissa-Dr means imbedded overlying

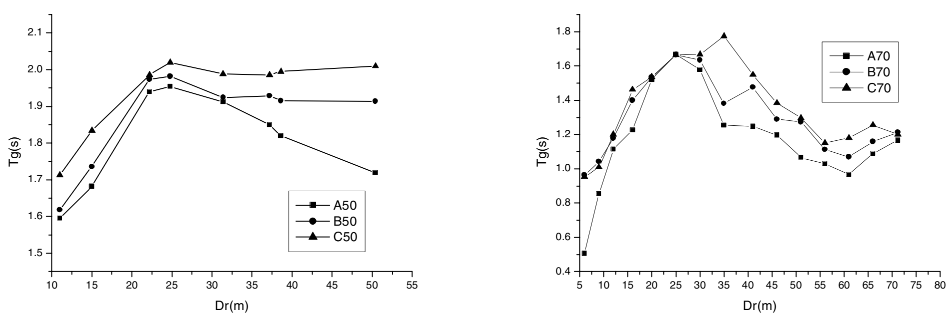
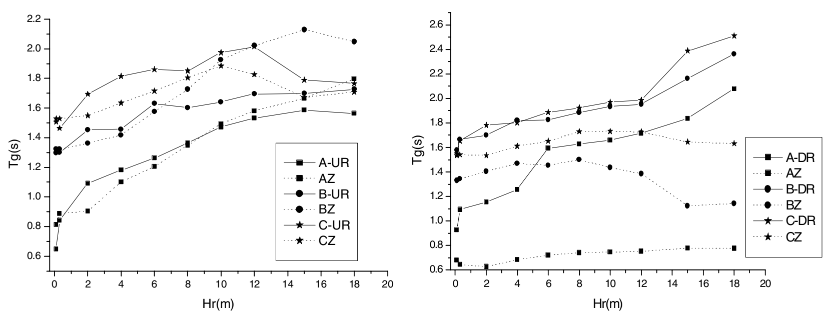


Figure 6 the effects of imbedded depths of soft interlayer on T_g s

depth of soft interlayer, whose unit is meters, and A50, B50 and C50 represent the outcome of profiles, whose thickness of overlying layer is 50m under A, B and C time-history, respectively, and other signals' meanings are analogous. Figure 6 indicates that as to profiles calculated, soft interlayer imbedded depths have remarkable effects on T_g s. If the imbedded depth of soft interlayer is less than 25 m, T_g increases with increasing the imbedded depth of soft interlayer; and if the imbedded depth of soft interlayer is more than 25 m, T_g on the whole increases with increasing the imbedded depth of soft interlayer. To the same profile, the higher is intensity of input ground motions and the bigger is T_g.

Then, the effects of changes of thickness of soft interlayer at different depths on T_g s are studied. Firstly, the profile with the thickness of overlying layer of 60 m , is selected, and 12 new profiles are formed by replacing the top second layer of the profile with soft layer, whose thicknesses rang from 0.1 to 18m. T_g s of these new profiles and normal profiles are calculated, as shown in Figure 7(a). In Figure 7, Hr represents thickness of soft interlayer, dotted line represents the outcome of normal profiles and real line the outcome of profiles containing soft layer. Secondly, by replacing the bottom layer of the profile with soft layer, whose thicknesses rang from 0.1 to 18 m, 12 new profiles are formed. T_g s of these new profiles and normal profiles are calculated, as shown in Figure 7(b). Figure 7 indicates that compared to



(a) (b)

Figure 7 Comparision between profiles with soft interlayer at the top and bottom and normal profiles

T_g s of the normal profiles, if soft interlayer at the top and bottom of profiles, T_g increases with increasing the thickness of soft interlayer, and that T_g s of profiles with soft interlayer on the whole are bigger than the values of normal profiles and especially T_g s of profiles with soft interlayer at the bottom are bigger remarkably.

CONCLUSION

The effects of soil layer construction on characteristic periods of response spectra are studied primarily in this paper. Researches indicate that the effects of soil layer construction on characteristic periods are remarkable. Under the same input ground motion, T_g increases with soft layer. It is deserved that T_g is affected by multiple factors. How T_g varies with the change of soil layer construction and input ground motion is a complex problem. Nevertheless, the obtained results in this paper have a certain value on further studying the field. T_g is one of the most important parameters to specify design spectra in code of seismic design, so it is necessary to continue to research the field.

FUNDING ACKNOWLEDGEMENT

The work reported on in this paper was undertaken with funding provided by the tenth Five-Year Plan, China Earthquake Administration.

REFERENCES

1. “Code for seismic design of buildings (GB50011-2001).” National Standard of the People Republic of China, 2001.
2. Liao Zhen-Peng, Li Xiao-Jun. “Linearization Method for Computing Earthquake Response of Ground Layered Soil.” Seismic Microzonation-Theory and Practice. Beijing: China Earthquake Press, 1989: 141-153
3 Idriss, I. M. , et al. “Seismic response of horzitonal soil layers.” ASCE. 1968; 94(SM4): 1003
4 Liao Zhen-peng, Li Da-hua. “An Two-Parameters Method for Scaling Design Earthquake Response Spectra”. Seismic Microzonation-Theory and Practice. Beijing: China Earthquake Press, 1989: 196-207
5 Yuan Xiao-ming, Sun Rui, Sun Jing, et al. “Laboratory experimental study on dynamic shear modulus ratio and damping ratio of soils.” Earthquake Engineering and Engineering Vibration. 2000; (4):133-139
6 Li Xiu-ling. “Effects of soil layer construction on surface ground motion parameters of earthquake[D].” Harbin: Institute of Engineering Mechanics, China Earthquake Administration, 2003.