REQUIREMENT FOR ERROR CONTROL OF NONLINEAR EXPERIMENTS OF SOILS

Xiaojian Liu[1], Rui Sun[2] And Xiaoming Yuan[3]

[1] *Doctor, Dept. of Geotechnical Engineering , Institute of Engineering Mechanics, Harbin. China*
[2] *Professor, Dept. of Geotechnical Engineering, Institute of Engineering Mechanics, Harbin. China*
[3] *Professor, Dept. of Geotechnical Engineering, Institute of Engineering Mechanics, Harbin. China*
Email: liuxiaojian000@126.com, iemsr@163.com, yxmiem@163.com

ABSTRACT :

Many researches in recent years have approved that the nonlinear behavior of soils has significant effect on the surface ground motion. The laboratory experiments on the relationship of the shear modular and damping ratio with the shear stain are complicated generally and existing results from various devices may be different in great extent. The experiment technique should be improved and the error should be limited in engineering accuracy. Therefore, the standard of error control should be provided, which is important for further work both on the experiment skills and improvement of equipment itself. However, there is an obvious shortage in the study on the standards of error limitation of the experiments results.
In this paper, the requirement for the error control of the experiments on the soil shear modular and damping ratio with the shear strain is studied and specification of accuracy limitation of the experiments is presented. The one of the key points in the paper is that establish relationship among the soil nonlinear proper variation, the surface ground spectrum and the spectra, and the other is that the structure response is taken as the base of measuring the soil nonlinear variation. The effect of the experimental error of the soil shear modular and damping ratio on the acceleration spectrum is investigated by using the simulation method. The typical models of soil layers under various kinds of inputting seismic waves are employed in the analysis first. Then, the specification of the error limitation of the soil shear modular and damping ratio is determined by the extents of the corresponding structure responses. Through the analysis, the standard of measuring accuracy of the soil shear modular and damping ratio with the intensity of the inputting seismic waves is attained and the scope of the soil shear strain with the intensity of the inputting seismic waves is also presented.

KEYWORDS: shear modular and damping ratio; nonlinear; error control; standard

1. INTRODUCTION

The shear modular ratio and damping ratio are the important parameters of soil dynamic feature, the necessary dynamic parameters in soil seismic response and the essential components in the seismic safety evaluation. It is well known that ground motion is influenced by the soil dynamic feature. The nonlinear experiment about relationship between shear modular ratio and shear strain, damping ratio and shear strain is very complicate. The result of the experiment also has big errors. So the experiment technique should be improved and the error should be limited in engineering accuracy. Therefore, the standard of error control should be provided, which is important for further work both on the experiment skills and improvement of equipment itself. However, there is an obvious shortage in the study on the standards of error limitation of the experiments results.

In this paper, the requirement for the error control of the experiments on the soil shear modular and damping ratio corresponding to the shear strain is studied and specification of accuracy limitation of the experiments is presented. One of the key points in the paper is that establish relationship among the soil nonlinear proper variation, the surface ground spectrum and the spectra, and the other is that the structure response is taken as the base of measuring the soil nonlinear variation. The effect of the experimental error of the soil shear modular and damping ratio on the acceleration spectrum is investigated by using the simulation method. The typical models of soil layers under various kinds of inputting seismic waves are employed in the analysis first. Then, the specification of the error limitation of the soil shear modular and damping ratio is determined by the extents of the corresponding structure responses. Through the analysis, the standard of measuring accuracy of the soil shear modular and damping ratio with the intensity of the inputting seismic waves is attained and the scope of the soil shear strain with the intensity of the inputting seismic waves is also presented.

2. SOIL MODELS AND PARAMETERS

Using single soil type, two profiles, four different inputting earthquake waves which the peak valve can be regulated as 98.1Gal (intensity Ⅰ)，196.2Gal(intensity Ⅱ)，392.4Gal (intensityⅢ). Meanwhile using one-dimensional equivalent linear method of soil seismic response, the inputting parameters are listed in table1 and table 2. Keeping the damping ratio constant, then regulating the dynamic shear modular ratio as ±3%，±6%，±9% based on the shear strain at 10^{-4}. It is because that the initial iterative shear modular ratio begins at shear strain 10^{-4} in the soil seismic response procedure.

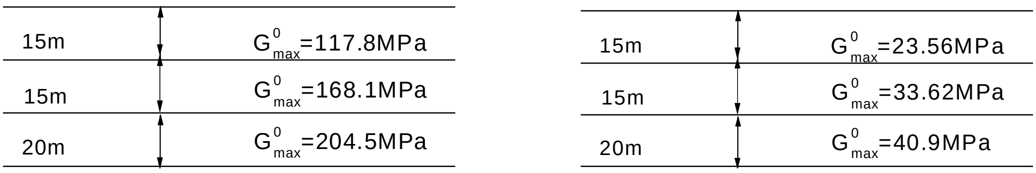

Figure 1 Soil profiles

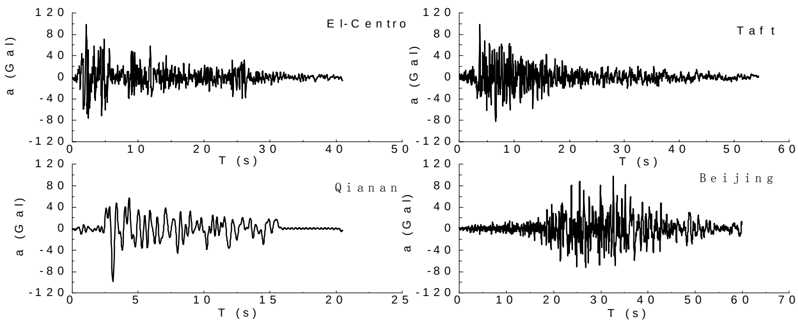

Figure 2 Inputting earthquake waves

Table1. Shear modular ratio used in analysis

G/G_{max}	$\gamma(10^{-4})$							
	0.05	0.1	0.5	1	5	10	50	100
Initial parameter	0.998	0.985	0.930	0.869	0.571	0.400	0.118	0.062
＋3％	0.999	0.989	0.946	0.897	0.635	0.466	0.148	0.080
＋6％	0.999	0.991	0.958	0.919	0.695	0.532	0.185	0.102
＋9％	0.999	0.992	0.967	0.947	0.742	0.560	0.201	0.112
－3％	0.997	0.981	0.914	0.843	0.507	0.334	0.088	0.044
－6％	0.997	0.979	0.902	0.817	0.447	0.270	0.051	0.033
－9％	0.997	0.978	0.893	0.791	0.400	0.260	0.035	0.022

Table2.Initial shear modular ratio and damping ratio

Initial parameter	$\gamma(10^{-4})$							
	0.05	0.1	0.5	1	5	10	50	100
Shear modular ratio	0.998	0.985	0.930	0.869	0.571	0.400	0.118	0.062
Damping ratio	0.007	0.010	0.014	0.031	0.074	0.096	0.127	0.133

3.SHEAR MODULAR RATIO CORRESPOND TO NONLINEAR CHANGE TREND & ERROR STANDARD

3.1 Influence of Shear Modular Ratio Error on Spectrum

Two profiles are used to get the influence of shear modular ratio error on the spectrum. From the following figures, many observations can be got. For intensity Ⅰ, shear modular ratio error has little influence on the acceleration spectrum, specially when the error below 6%, almost has no influence on the spectrum. When the error is 9%, it exhibits larger high frequency and lower low frequency. When the error is -9%, it exhibits lower high frequency and larger low frequency.

For intensity Ⅱ, shear modular ratio error's influence on the acceleration spectrum has become larger, specially when the error below 6%, has obviously influence on the spectrum. When the errors are 6% and 9%, it exhibits obviously larger high frequency and lower low frequency. When the errors are -6% and -9%, it exhibits obviously lower high frequency and larger low frequency.

For intensityⅢ, shear modular ratio error's influence has notable influence on the acceleration spectrum. Even when the errors are +3% and -3%, the shape of spectrum had large change. When the error is positive, it exhibits obviously larger high frequency and lower low frequency, when the error is negative, it exhibits opposite influence.

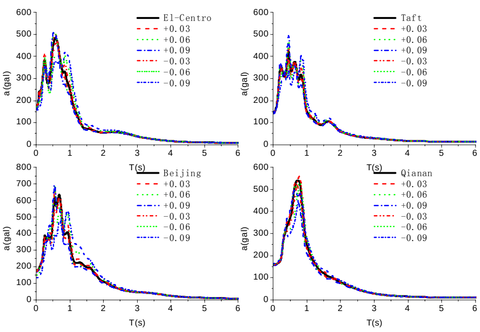

Figure 3 Response spectra of intensity Ⅰ for profile A

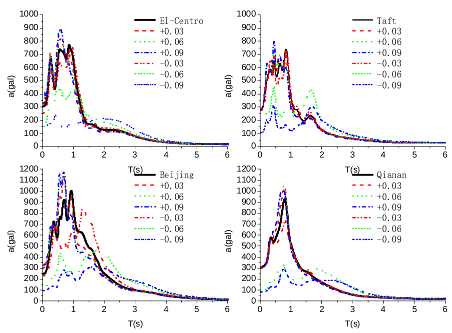

Figure 4 Response spectra of intensity Ⅱ for profile A

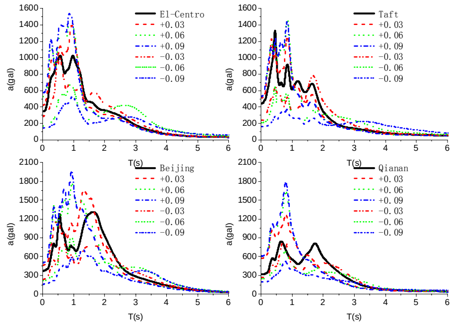

Figure 5 Response spectra of intensityIII for profile A

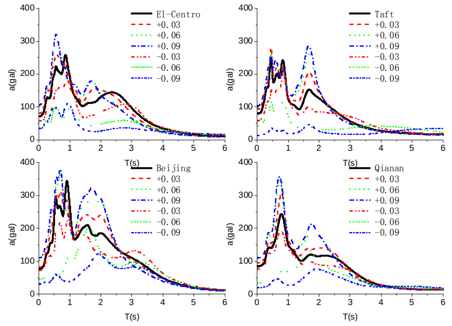

Figure 6 Response spectra of intensity I for profile B

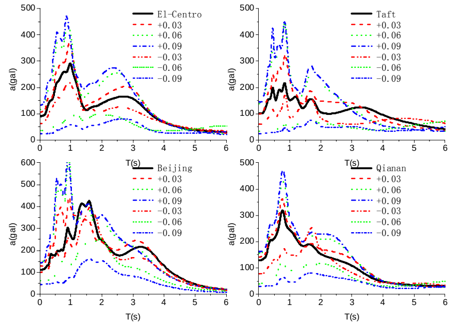

Figure 7 Response spectra of intensity II for profile B

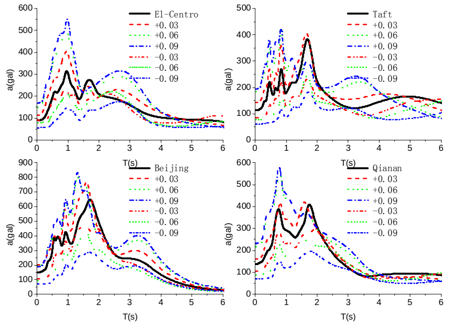

Figure 8 Response spectra of intensityIII for profile B

Characteristic period T_g and Seismic influence coefficient α_{max} are used as indicators to research the shear modular ratio error's influence on the soil seismic response. T_g and α_{max} can be calculated by using the following expression 3.1 and 3.2.(Liao zhenpeng and Li dahua,1989).

$$\alpha_{\max} = 2.25 * \frac{A_{\max}}{980} \qquad (3.1)$$

$$T_g = 4.44 * \frac{V_{\max}}{A_{\max}} \qquad (3.2)$$

To minimum the discrete result of one wave, the characteristic period T_g and seismic influence coefficient α_{max} got from four waves should be averaged ,then α'_{max} and T'_g are the average description. From the calculation result, to different inputting wave peak value, the strain ranges that fit the iterative request are different. To the profile A, the strain range is at $1*10^{-4}$, $5*10^{-4}$, $5*10^{-3}$ for intensity Ⅰ, Ⅱ, Ⅲ. So, when researching the modular ratio error's influence on the ground motion, the shear strain at 10^{-4} can not be used simply. The inputting 98.1Gal wave value in the following figure corresponds to abscissa value 0, 0.03, 0.06, 0.09. The other two are separately corresponding to 0, 0.11, 0.22, 0.3 and 0, 0.25, 0.56, 0.7.

Similarly, to the profile B, the strain range is at $1*10^{-3}$, $5*10^{-3}$, $1*10^{-2}$ for intensity Ⅰ, Ⅱ, Ⅲ. The inputting 98.1Gal wave value in the following figure corresponds to abscissa value 0, 0.165, 0.33, 0.4. The other two inputting waves are separately corresponding to 0, 0.25, 0.57, 0.7 and 0, 0.29, 0.65, 0.81.

The relationship curve between relative change of T_g and relative change of shear modular ratio can be got using following equation.

$$\frac{T_g - T_{g,0}}{T_{g,0}} = a\left(\frac{G/G_{\max} - G/G_{\max,0}}{G/G_{\max,0}}\right)^b \tag{3.3}$$

$G/G_{\max,0}$——initial shear modular ratio;
$G/G_{\max}$——shear modular ratio after changing;
$T_{g,0}$——characteristic period in initial shear modular ratio;
T_g——characteristic period after changing the shear modular ratio.

Similarly, the relationship curve between relative change of $\alpha_{\max}$ and relative change of shear modular ratio can be got.

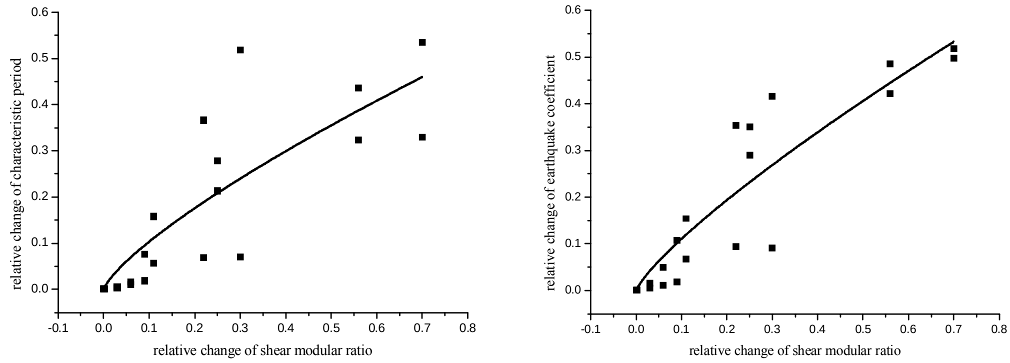

Figure 9 Influence of Shear modular ratio on characteristic period and seismic influence coefficient in Profile A

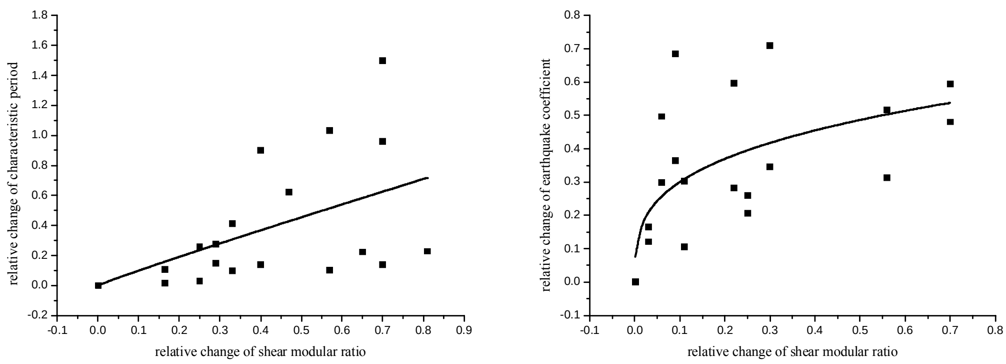

Figure10 Influence of shear modular ratio on characteristic period and seismic influence coefficient in Profile B

3.2 Influence of Damping Ratio Error on Spectrum

Initial parameters are the same as above. Damping ratio error range can be determined by using Yuan xiaoming (2000) gave the averaging curves, recommended values and envelopes of damping ratio versus shear strain for six types of soils in China. The range of damping ratio varies from -30% to 30%, the maximum is +45%, that seven different damping ratios -10%,-20%,-30%,10%,20%,30% and 45% can be got.

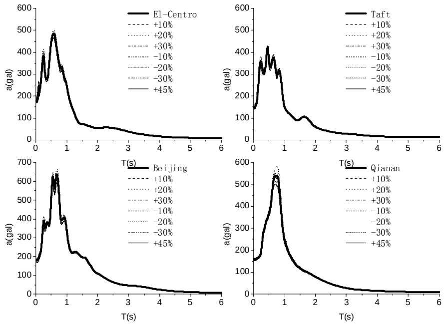

Figure 11 Response spectra of intensity Ⅰ for profile A

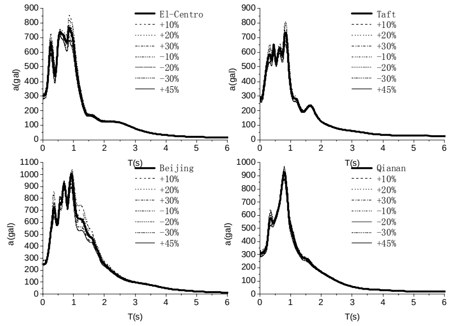

Figure 12 Response spectra of intensity Ⅱ for profile A

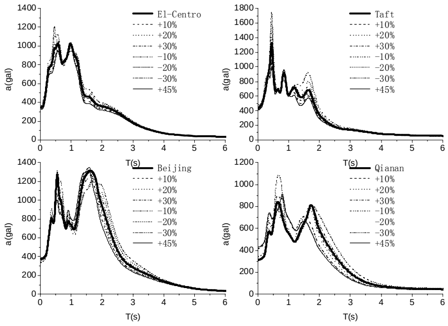

Figure 13 Response spectra of intensityⅢ for profile A

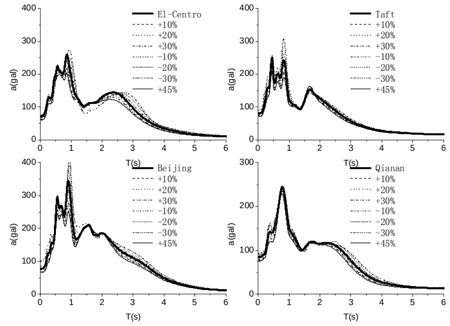

Figure 14 Response spectra of intensity Ⅰ for profile B

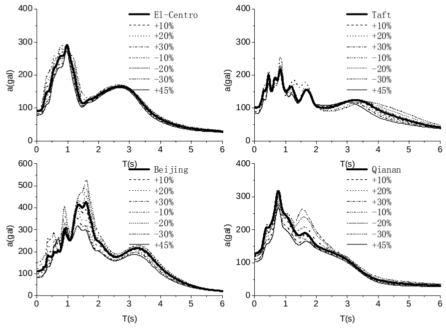

Figure 15 Response spectra of intensity Ⅱ for profile B

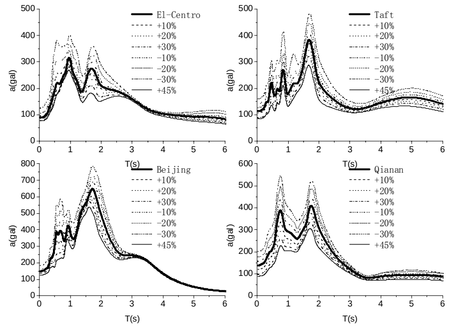

Figure 16 Response spectra of intensityⅢ for profile B

4. DETERMINATION OF ERROR STANDARD OF DYNAMIC NONLINEAR TEST

Basing on the structure reaction, the request on accuracy of the error standard of dynamic nonlinear test can be solved. Through the analysis, the standard of measuring accuracy of the soil shear modular and damping ratio with the intensity of the inputting seismic waves is attained and the scope of the soil shear strain with the intensity of the inputting seismic waves is also presented.

According to 'Seismic Design of Building Code' in China, the average seismic influence coefficient got from inputting earthquake waves that compared with mode decomposition method do not differ more than 20%.

Compare the different modular ratio and damping ratio with seismic influence coefficient α_{max} curve, if the value at every period point is not large than 20%, that it has no influence on the ground motion, if not, it can not fit the request of accuracy. The error standard of dynamic nonlinear test could be made based on above.

For intensity Ⅰ, the shear strain range is about 10^{-4} which corresponds to the assumptive error's point, the accuracy of shear modular ratio error can only be determined. Compare the different inputting waves in different modular ratio error, that the average seismic influence coefficient can be got. The curve that reflects the average modular ratio influence are showed in figure 17. When the error is -9%, the accuracy is not fit the request in the period 1 – 2 seconds. So, to the moderate earthquake, the shear modular error at shear strain 10^{-4} should be controlled between 6% and -6%.

5. CONCLUSION

Several results are got in this article. The effect of shear modular ratio on ground motion is studied. The quantitative relation between relative change of shear modular ratio and characteristics period is proposed for typical sites. Because the error standard of soil dynamic non-linear test is less studied, so solving quantitative standard of soil non-linear test is presented, i.e. basing on structure reaction. The error standard of soil dynamic non-linear test under medium earthquake loading is proposed.

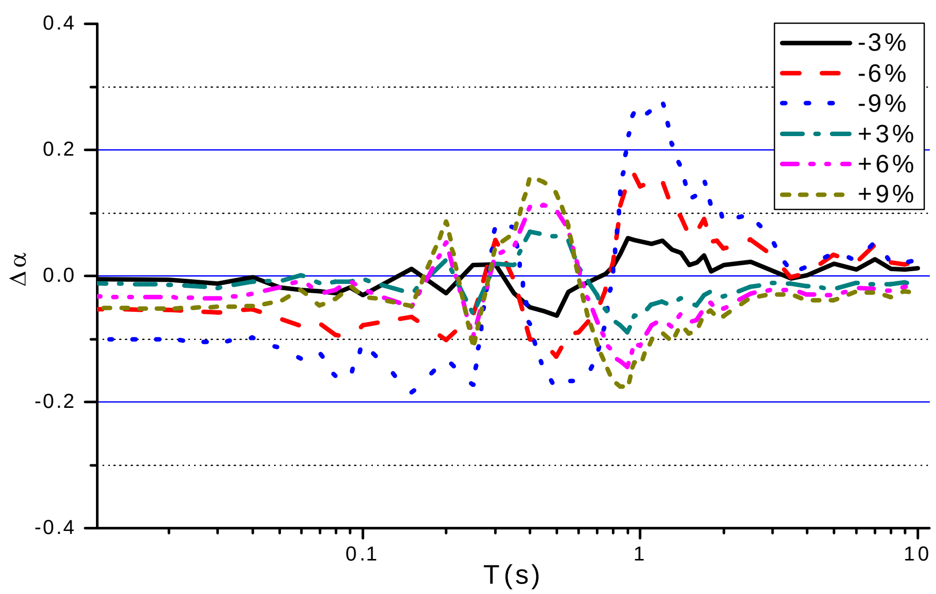

Figure17. The average result of seismic influence coefficient α_{max} for intensity Ⅰ

REFERENCE

Lan jingyan, Bo jingshan and Lu yuejun, “Study on the effect of shear wave velocity on the design spectrum”, Technology for earthquake disaster prevention, Vol. 2, No. 1, 19-24, Mar., 2007.
Liao zhenpeng, Li dahua, “An empirical model for scaling design earthquake response spectra”, Seismic microzonation [M], Earthquake Press, Beijing, 196-207, 1989.
Yuan xiaoming, Sun rui, ect, “Laboratory experimental study on dynamic shear modulus ratio and dam ping ratio of soils”, Earthquake engineering and engineering vibration, Vol. 20, No. 4,133-139, Dec, 2000.