RECENT RESEARCH ON PREDICTION OF SEISMIC SUBSIDENCE OF LOESS

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SUMMARY

Prediction has been done on the earthquake disasters of several loess sites in Lanzhou area through the test research of loess subsidence under different earthquake loading. The prediction results of loess subsidence quantities are different when loess are under the irregular seismic loading and constant amplitude sinusoid loading individual.

INTRODUCTION

From the earthquake disaster examples and loess subsidence research, it is proved that loess will produce additional settlement called subsidence. The subsidence quantity can be up to 10cm. For example, the Ms 5.8 earthquake occurred in loess hills areas in Yongdeng County of Gansu province of China in 1995, and the meizoseismal area intensity reaches 8 degrees. In areas of 7—8 degrees, loess crack and sunk, slopes are destabilized, and the landslide and collapse can be seen universal. The loess subsidence of meizoseismal area reaches 20—40 cm and severely subsidence occur in the middle of loess layers. This shows that, in loess areas, earthquake disaster has nearly relation with its subsidence. Loess subsidence is the directly reason which cause disasters such as slope destabilization, foundation settlement and so on. So to predict the quantity of loess foundation subsidence that may be produced in the future earthquake became an important criterion to plan for earthquake disaster.

Loess subsidence test research mainly is done under the constant amplitude sinusoid equivalent earthquake loading of single-frequency before. It is well known, seismic loading is a random dynamic loading. So, it is a simulate method to take the loess dynamics parameters obtained under the constant amplitude sinusoid equivalent earthquake loading as parameters using the soil-structure response analysis under earthquake loading. In this subsidence test, irregular earthquakes loading are applied on loess samples directly. The result is used to predict subsidence disaster of loess sites, and is studied corresponding to the result of test under constant amplitude sinusoid earthquake loading (the frequency is 1Hz). Through prediction research of loess subsidence test under different seismic loading, the reliable prediction result will be used in foundation

LOESS SUBSIDENCE TEST UNDER THE IRREGULAR SEISMIC LOADING [1]

The irregular seismic loading used in test

In order to prove the pertinence of loess, several irregular seismic loading time-history (Fig 1) chosen are the bedrock input wave and loess response time-history of Lanzhou seismic microzonation and seismic risk analysis. It is typical irregular seismic loading that may occur in the future in Lanzhou loess area. The parameters can be found in Table 1.

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Table 1 Parameters of seismic loading used in tests

Name of irregular loading	Predominant period	Effect duration	Loading type	Simulated intensity
Lanzhou artificial earthquake wave	0.17	11.0	Shuttle	8
Lanzhou loess response time-history (I)	0.30	15.0	Shuttle	VIII
Lanzhou loess response time-history (II)	0.50	25.0	shuttle	8

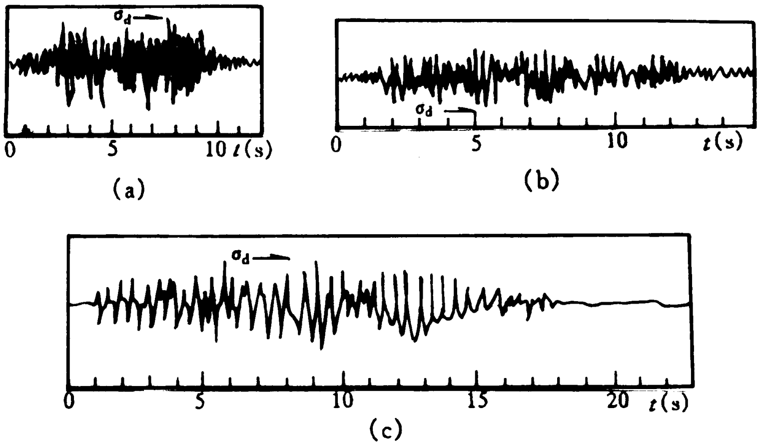

Fig.2 The time histories of irregular seismic loading used in the test.

(a) Lanzhou artificial earthquake wave;
(b) Lanzhou loess response time history(I)
(c) Lanzhou loess response time history(II)

Loess samples and the test method

The in place loess samples of test are obtained from different depth of exploratory well in the site being predicted. The samples are cut into columns 100mm high that the diameter is 50mm, then dynamic triaxial test apparatus consolidates the samples. The consolidation stresses are simulating to the original stress of undisturbed soil samples and the stress under additional building loading. Axial stress σ_2 equals to the weight of overlay soil or 196KPa, and the lateral consolidation stress $\sigma_3 = K_0\sigma_2$ (K_0=0.59). When the deformation in consolidation does not increase any more, dynamic loading is applied to the samples and the residual strain caused by dynamic loading is measured. So a subsidence curve (σ_d--ε_p relationship) can be obtained under the same consolidation stress when different amplitude dynamic stress σ_d applies on a group sample including 4—5 ones of similar parameters, as the Fig 2 perform.

In order to use proper dynamic parameters in the earthquake disaster prediction of ground, in this paper, subsidence tests are performed with each of a group of prediction site samples under irregular seismic loading and the equivalent loading, constant amplitude sinusoid loading. The loess subsidence curves under different earthquakes loading are obtained convenient for calculating subsidence quantity.

METHOD OF SEISMIC SUBSIDENCE QUANTITY PREDICTION

It is important to predict seismic subsidence quantity of foundation to provide constantly and reliable scientific dates used for engineering foundation seismic resistance design and disposal. In this paper, the method of loess subsidence test is applied to analyze, calculate and predict subsidence quantities of loess sites under different loading. Such as the following:

(1). At the first, the loess site predicted is divided into several layers according to its different physical properties, and subsidence curves come from test with the undisturbed samples token from each middle of layers.

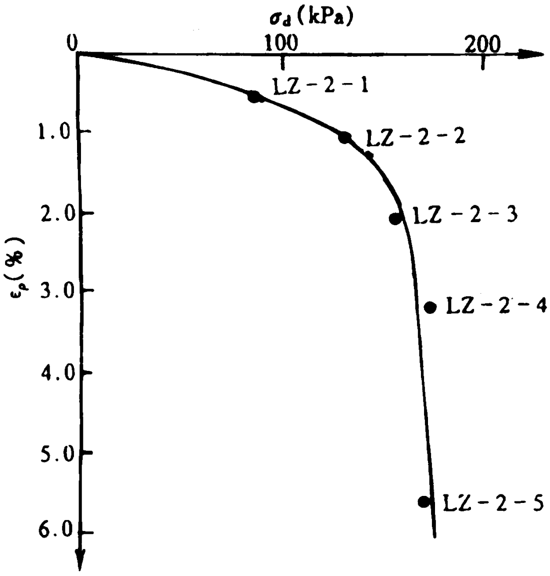

Fig. 2 Curves of seismic subsidence

(2). The possible dynamic shear stress τ_{di} of stratum is calculated by ground horizontal maximal acceleration a_{max} of local seismic microzonation and seismic risk analysis.

$$\tau_{di} = 0.65 * r * h * a_{max}/g * K_d \tag{1}$$

Which r is the density of loess (KN/M^3), h is the stratum depth (M), a_{max}/g is the seismic coefficient and K_d is dynamic reduction coefficient. (Table 2)

τ_{di} is calculated by the formula $\sigma_d=2\ \tau_d$ and form subsidence curve the seismic subsidence coefficient ε_{pi} can be obtained which corresponding to σ_{di}. The stratum seismic subsidence quantity (S_{di}) is the product of ε_{pi} and the depth of stratum h_i.

$$S_{di}.= \varepsilon_{pi} * h_I \tag{2}$$

(3). The total subsidence quantity (S_d) of site is the sum of each separate layer quantity. So the curve of the total subsidence quantity and seismic acceleration (intensity I) will be drawn and the subsidence prediction under VII,VIII and IX intensity brought out.

$$S_d= \sum_{i=1}^{n} \varepsilon_{pi} * h_i \tag{3}$$

Table 2 Loess dynamic stress reduced coefficient

Depth h(m)	0	1.5	3.0	4.5	6.0	7.5	9.0	10.5	12.0	15.0
Stress reduced coefficient (K_d)	1.000	0.985	0.975	0.965	0.955	0.935	0.915	0.895	0.85	0.825

PREDICTION AND ANALYSIS OF SEISMIC SUBSIDENCE QUANTITY

In this paper, above-mentioned method is used to predict the seismic subsidence quantities of several loess sites in Lanzhou under irregular seismic loading and the equivalent constant amplitude sinusoid loading. The prediction is as Fig 3 and Table 3 display. In Fig 3 the predicted curves of loess total subsidence quantity and seismic acceleration educed from subsidence tests, which provide loess subsidence quantities according to different seismic acceleration. In Table 3, the possible maximal subsidence quantities are determined by the curves in Fig 3 when sites suffer earthquake of VII,VIII and IX intensity.

From Fig 3 and Table 3 a conclusion can be drawn that the loess subsidence quantity increase along with the increasing of seismic acceleration or intensity under different earthquake loading except of tendency. In general, the subsidence quantity under irregular seismic loading is littler than that of constant amplitude sinusoid loading.

The prediction in Fig 3 also shows that different predominant period, peak value and effective duration cause different subsidence quantity prediction of loess.

In a word, the subsidence quantity of loess in a same site increases with the increasing of seismic acceleration or intensity by any shock excitation. In VII intensity, each loess site has slight subsidence or no distinct subsidence. In VIII intensity, these sites may be destroyed slightly or more. If the intensity is up to IX, these sites will be damaged heavily.

Table 3 seismic subsidence quantities prediction of loess sites

No. Of sites	Calculating depth(m)	Mean of soil physical parameters			Seismic loading	Maximal subsidence quantities of different intensity		
		Density (kN/m^3)	Water content(%)	Porosity ratio		VII	VIII	IX
Lz-1	20	15.68	18.55	1.008	Lanzhou loess seismic response time-history(I) Constant amplitude sinusoid loading	0.95 3.05	7.50 14.70	91.50 142.40
Lz-2	20	14.50	8.90	0.994	Lanzhou artificial earthquake wave Constant amplitude sinusoid loading	0.15 1.80	2.00 5.75	44.28 33.60
Lz-3	20	15.05	11.34	0.959	Lanzhou loess seismic response time-history(II) Constant amplitude sinusoid loading	0.65 2.85	3.25 12.70	37.50 115.20
Lz-4	20	14.90	11.65	0.991	Lanzhou loess seismic response time-history(II) Constant amplitude sinusoid loading	1.90 3.80	6.65 15.20	51.20 105.40

The research production in reference from 2 to 4 shows that wind deposited loess with microstructure of pole grains, formed in Q_3 period, lies in higher terrace, has lower water content. But its subsidence quantity increases distinctly as the humidity content rise. It is to say that, even in VIII seismic intensity, the predicted loess sites might be destroyed severely without controlling the humidity of foundation if some water access into soil.

The author use test method to predict and study loess subsidence under different seismic loading. The contrasting research proves that there are difference between the result of irregular seismic loading and that of constant amplitude sinusoid loading. Obviously, in dynamic triaxial tests, the foundation subsidence prediction is more accurate using irregular time-history directly, which transfer from earthquake time-history by local seismic risk analysis and seismic microzonation.

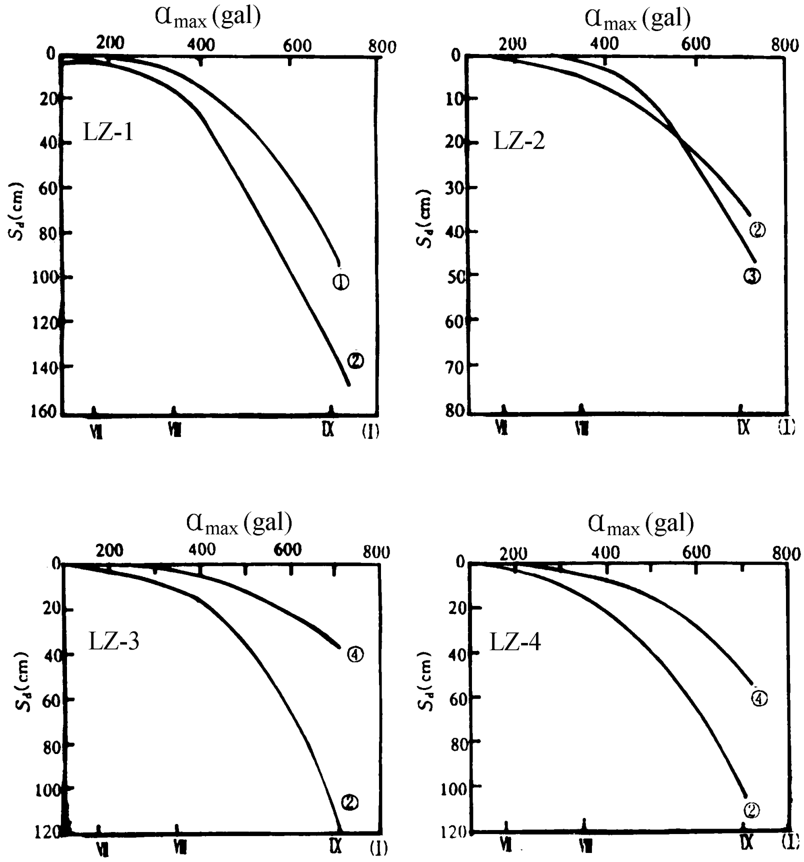

Fig. 3 predicted curves of seismic subsidence quantities on sites under different seismic loading.
① Lanzhou loess response time history (I);
② Constant amplitude sinusoid loading;
③ Lanzhou artificial earthquake waves;
④ Lanzhou loess response time history (II).

CONCLUSION

Through the test prediction and contrasting analysis of loess sites subsidence under different seismic loading, two preliminary major conclusion are drawn as following:

(1) Under different seismic loading, loess subsidence quantity increases with the increasing of seismic acceleration or intensity expect of different tendency. To a same site, under irregular loading, the subsidence quantity prediction is littler than that of value under constant amplitude sinusoid loading. The subsidence predictions under two above-mentioned loading show definite difference.

(2) Loess subsidence relates to the predominant period, peak value and effective duration of irregular loading. So, in dynamic triaxial tests, the foundation subsidence prediction is more accurate using irregular time-history directly, which transfer from earthquake time-history by local seismic risk analysis and seismic microzonation. The prediction is more reliable.

REFERENCE

1. Jun WANG & Lanmin WANG,(1994). Laboratory research of loess subsidence under different seismic, Proc.The fourth conference on soil dynamics. p.138—141, Zhejiang university press, China.
2. Lanmin WANG & Zhenzhong Zhang, (1992). The prediction method of loess subsidence quantity in earthquake, Nature disasters journal, p.85—94, China.
3. Zhenzhong ZHANG & Lanmin WANG, (1992). Subsidence disasters of cities in loess areas, Proceeding of the fourth national conference on engineering geology (1), p. 364—379, China.

Ruwen DUAN, Lan LI & Jun WANG,(1997) the subsidence and disasters evaluation of loess with different characters, Northwestern seismological journal, (Supp), p.88—93.