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Research on Comparison of the Maximum Dynamic Shear Modulus Test

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Abstract

Dynamic soil modulus and damping ratio are the two basic parameters to describe dynamic deformation characteristics of the soil. There are three ways to obtain soil dynamics parameters i.e. field test, laboratory test, and calculating empirical. Silt loam samples were collected from Dongying area in this study. In order to get the maximum dynamic shear modulus, the following methods were adopted. The shear wave velocity was tested in field using single-hole method, and the maximum dynamic shear modulus capacity was obtained based on the calculation result of the shear wave velocity. The paper compared the results obtained by three methods and got some useful conclusions. The maximum dynamic shear modulus value calculated by field test was close to the corresponding value from the laboratory dynamic triaxial test, while the value obtained from the empirical formula was significantly lower. However, as the theory, method and collation of data for two kinds of tests were different, their test results were not exactly the same.

Keywords: Shear wave velocity; Dynamic triaxial; Maximum dynamic shear modulus; Seismic safety evaluation; Soil dynamics

1. Introduction

Since the dynamic shear modulus is the key factor for seismic safety evaluation of an engineering site, the reasonableness of this parameter will directly affect the safety and economical efficiency of projects [1-2]. Many scholars carried out lots of experiment on the soil dynamic shear modulus, made many

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valuable research results on soil dynamics, and played a great role in promoting the development of earthquake engineering [3-5]. There are several ways to obtain soil dynamics parameters. In this paper, the silty clay samples were collected from Dongying area using several ways to compare the maximum dynamic shear modulus. The following methods were adopted: (1) We tested the shear wave velocity in field using single-hole method, and obtained the maximum dynamic shear modulus capacity based on the calculation result of the shear wave velocity; (2) Dynamic triaxial tests of undisturbed soil samples were carried out to obtain the dynamic shear modulus in the laboratory; (3) We adopted the calculation formula proposed by many scholars to estimate the maximum dynamic shear modulus. Based on this idea, the obtained results values were compared. The results may have a significant value for us to better understand dynamic behaviors of deposited soils in the area.

2. Samples, Instrument and Test methods

2.1. Samples

The silty clay samples were collected from Dongying earthquakes zoning. Dongying is located in the northern part of Shandong Province the Yellow River delta South coast of Bohai Bay and western of Laizhou Bay. The characteristics of historical earthquakes in this region were strength and higher frequency. In the history it has been a large-scale destruction soil liquefaction of the foundation, so the earthquake disaster area should be sufficient attention. We chose a control drilling. The stratum in which the control drill hole locates is the Quaternary strata of silt, sand, silty clay, clay and so on. The ground is relatively flat, and the lithology of upper part is small change. The strata is close to the horizontal. The hardness and lithology of soil is relatively evenly distributed in the plane, is slightly different in the thickness. The lithology of lower part is slightly different, but the difference is small. Six samples were selected in the control drill. The physical character and lothological description is shown in the table 1.

Table 1. The information of experiment samples

No.	Depth (m)	Lothological description	Density (g/cm^3)	Moisture (%)	Plasticity index (Ip)	Pore ratio(e)	Shear wave velocity （m/s）
DY5	16.8	Gray - yellow and gray clay, containing a small amount of detrital mica	1.79	39.8	17	0.85	159
DY6	30.8	brown-yellow clay, containing iron-manganese oxide	2	25.1	17	0.85	192.5
DY7	40.5	Brown yellow - gray silty clay containing shell debris	2.12	21.9	10	0.75	256
DY8	58.4	Brown yellow - brown-gray silty clay containing shell debris	2.07	20.2	10	0.75	303
DY9	79.8	Grey yellow silt, containing a small amount of detrital mica	2.19	16.1	10	0.75	313
DY10	88.5	Grey yellow - yellow brown silt containing shell debris	2.1	16	8	0.65	363.5

2.2. Experimental instrument and methods

We chose the suspension-type wave velocity logging method to measure the shear wave velocity, which uses the sensors placed in the hole to receive the source of the S-wave arrival time to determine the stratum velocity of the place drill hole located. The instrument is XG-I type hanging wave velocity logging instrument produced by Langfang Dadi Geotechnical Engineering Detection Technology

Development Co., Ltd. The instrument has the function of time-sampling, superposition, filtering, signal enhancement, suppression impatient voice and on-site real-time calculation, display the measured waveform and test results and so on. The power supplies pulse current in the test. It is impelled the electromagnetism seismic source inspired P • S wave transferring along the wall formation .The detector receives vibration P • S-wave signal and converted into electrical signals, recorded by the recording instrument. Test pitch is 1.0 m. sampling is 2048 points .The sampling interval is 50 or 100μs. We can calculate the value of the velocity by the two P • S-wave first-arrival time difference between the two strata.

The dynamic triaxial test apparatus is the DDS-70-axis computer-controlled electromagnetic vibration test system producted by the Institute of Beijing New Technology Application. The DDS -70 dynamic three-axis computer-controlled electromagnetic vibration test system is to study the dynamic properties of soil in the laboratory, including the host, electric control system, static pressure control system and computer system, etc. The maximum axial dynamic pressure is up to 1370 N, the lateral pressure is 0 ~ 0.6 MPa, the back pressure is 0 ~ 0.3 MPa, the frequency range is 1 ~ 10 Hz, the maximum allowable axial displacement is 20 mm.

3. Experimental calculation method and results

3.1. Maximum dynamic shear modulus obtained by the use of shear wave velocity

The shear wave velocity test of the control borehole was measured per meter by point testing. The shear wave velocity calculation formula of each measuring point as follows:

$$v_i = \mathrm{H}_i /(t_i \cos\alpha_i - \sum_{j=1}^{i-1} \frac{H_j}{v_j}) \tag{1}$$

In equation: Hi——The thickness between i and i-1 measuring point;

ti ——The SH-wave travel time of i measuring point

αi——The elevation of the i measuring point to the ground source

The shear wave velocity was obtained by the calculation and analysis based on the above equation. According to the shear wave velocity of field test and wave theory, soil dynamic shear modulus formula as follows:

$$G\max = \rho \mathrm{V}^2 \tag{2}$$

Where ρ is soil density; V as the soil shear wave velocity. The maximum dynamic shear modulus value obtained by shear wave velocity was in Table 2.

Table 2. Comparison of three methods to obtain the resulting value

NO.	DY5	DY6	DY7	DY8	DY9	DY10
Shear wave velocity	45.25	131.07	78.56	190.04	214.55	277.48
dynamic triaxial test	50.75	118.96	78.46	178.31	194.15	236.36
Empirical test	19.38	27.4	40.59	53.2	64.07	70.42

3.2. Maximum dynamic shear modulus obtained by the use of dynamic triaxial apparatus

In the dynamic triaxial test, soil samples under load at all levels of axial stress (P) and axial strain (ε) history will be recorded, by the stress-strain time-stress-strain hysteresis curve plotted by the hysteresis curve of B point the stress-strain values of the sample can be obtained axial modulus E, soil samples can be obtained from the E-class loads in the modulus:

$$E = \frac{P_B}{\varepsilon_B} \tag{3}$$

$$G = \frac{E}{2(1+\nu)} \tag{4}$$

In equation, P_B, ε_B is stress and strain corresponding to point B of hysteresis loop respectively. ν is the value of Poisson's ratio determined by soil type. The obtained different amplitude modulus at all levels of load, while statistical analysis, the stress-strain relationship with the hyperbolic function is:

$$\frac{1}{G} = A + B\gamma \tag{5}$$

$$\tau = \frac{\gamma}{A + B\gamma} \tag{6}$$

In equation, τ and γ for the shear stress and shear strain amplitude, A and B for the regression constant, if make τ / = G, then:

$$\frac{G}{G_{\max}} = \frac{1}{(1 + \gamma B / A)} \tag{7}$$

If 1 / G for the vertical axis, γ as the abscissa, the results marked on the chart, similar to using a straight line to indicate their relationship, obviously when γ → 0, we can obtain coefficient A equal to coefficient of the maximum shear modulus, that is, 1/Gmax. The result data was shown in Table 2.

3.3. Maximum dynamic shear modulus obtained by the use of empirical formula

Chen G.X. et al (1995)[(4)] established the empirical correlation for various types of soil based on a large number of test measurement data in accordance with the most common indicators of physical properties of Ip and σ_0:

$$G_{\max} = \left[a_1 + a_2 * \exp\left(-a_3 Ip\right)\right] * \mathrm{Pa} * (ó_0/\mathrm{Pa})^{1/2} \tag{8}$$

a1, a2 and a3 parameter in the formula are with reference to Chen G.X. et al (1995). The formula can be applied to ground vibration zoning and similar tasks (ie. a large number of different locations, different soil types, is not needed to do a special test, and the formula is simple). The obtained results data was shown in Table 2.

4. Discussion

From the Fig1, the maximum dynamic shear modulus value of various layers calculated by the on-site shear wave velocity test, was close to the value obtained by laboratory cyclic triaxial. The corresponding values from the empirical formula were significantly lower. As the theories, experimental methods and data collation of two tests were different, their experimental results were not the same. Dynamic shear modulus of soil as an important indicator of dynamic properties of soil, with the dynamic shear strain amplitude varies. For the time being, the in situ shear wave velocity tests mainly applicable to small strain conditions, and this may be more reliable than laboratory results. Because the scene conditions is more realistic, on-site testing techniques such as cross-hole and the single hole method in this test is also already mature. Relatively speaking, the theory is more solid and laboratory technology also meets the requirements. Field test techniques cannot be replaced by laboratory work. Because from the perspective of the study, test conditions and the varied parameters can be set and controlled in laboratory, to promote theoretical development.

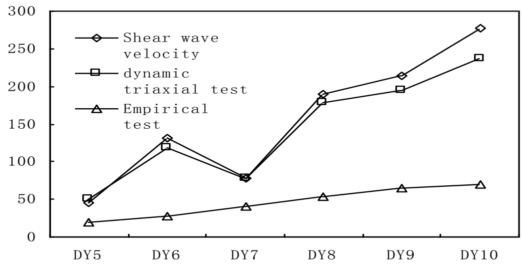

Fig. 1 Comparison of three methods to obtain the resulting value

5. Conclusion

Based on the test results through three methods, the maximum dynamic shear modulus value calculated by field test was close to the corresponding value from the laboratory dynamic triaxial test in the small strain, while the value obtained from the empirical formula was significantly lower.

The difference between on-site testing and laboratory testing conditions should be considered. The laboratory theory needs to be amended. In addition, some on-site working conditions cannot be simulated completely in laboratory. The on-site testing and laboratory testing were complementary. The combination of on-site test and laboratory test can be more reliable access to dynamic shear modulus of soil, and other dynamic parameters.

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References

[1] Yuan X.M.,Sun R., Sun J, et al. Conventional soil type dynamic shear modulus ratio and damping ratio of pilot study [J]. *Earthquake Engineering and Engineering Vibration,* 2000, 20(4):133-139.

[2] Lu Y.J., Tang R.Y., Seabed soil type dynamic shear modulus ratio and damping ratio of pilot study [J]. *Disaster Prevention and Mitigation Engineering*, 2003, 23 (2): 35-42.

[3] Sun J, Yuan X.M. Dynamic soil modulus and damping ratio of A Review [J].*World Earth-quake Engineering,* 2003,19 (1) :262-264.

[4] Chen G.X., Xie J.F., Zhang K.X., Dynamic soil modulus and damping ratio of the empirical estimation [J].*Earthquake Engineering and Engineering Vibration*, 1995,15 (1) :73-84.

[5] Liu X., Z., Chen G, X., Zhu D,H. SuNan region's newly deposited soil dynamic shear modulus ratio and damping ratio - Experimental Research [J] . *Journal of Natural Disasters*, 2006, (153):116-122. T

[6] Chen G.X., Liu X., Z., Zhu D.H., et al. Nanjing recently deposited soil dynamic shear modulus ratio and damping ratio of the pilot study [J]. *Journal of Geotechnical Engineering*, 2006.28 (8):1023-1027.

[7] Martin P .P. Seed H. B.One- Dimendional Dynamic Ground Response Analyses [J].*ASCE*.1982,108 (7):935—954