Dynamic-Triaxial Tests of Dynamic Shear Modulus and Damping Ratio for sandy silt in Beijing area

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Abstract. To study on relationship between dynamic shear modulus and damping ratio with shear strain, a new dynamic-triaxial test is performed on sandy silt in Beijing area. The testing data of the dynamic-shear modulus are compared with the existing statistical data in Beijing area and the statistical curve to prove the rationality of the test results. Comparison presents a good agreement.

1. Introduction

In recent years, urban earthquake disaster reduction has become a major concern in earthquake engineering with the frequent occurrence of strong earthquake\textsuperscript{[1]}. Many scholars have found that if the nonlinear dynamic parameters of the soil are not accurate, there will be a great differences in calculation of ground motion, indicating that the dynamic characteristics of soils have a significant impact on ground motion\textsuperscript{[2]}. In the face of increasingly prominent earthquake disaster reduction, it is recognized that the dynamic characteristics of soils are an important factor in the design and construction of seismic safety. It is a great important to study the dynamic characteristics of soils for urban earthquake disaster reduction\textsuperscript{[3]}. The dynamic shear modulus and damping ratio of soils are the two primary parameters that reflect the dynamic characteristics of the soils, in order to determine the dynamic shear modulus and damping ratio of soils, many scholars have conducted extensive research. But due to the variability of the soils and the level of test equipment, the study of this issue is complicated\textsuperscript{[4]}. Generally, the dynamic shear modulus and damping ratio of soils are always obtained on testing, if no testing data, they are consulted on specifications. However, researching shows\textsuperscript{[4], [5]}, the parameters given in specifications are not practical, the regional is an important factor on selection of soil dynamic parameters. There have obtained some valuable results in connection with specific area. Qinglong Lan, et al.\textsuperscript{[6]} has given the soil dynamic parameters with 134 dynamic-triaxial testing data in Tai-yuan area, Guoxing Chen, et al.\textsuperscript{[7]} has analyzed the characteristics of the newly deposited soil dynamic parameters in Nanjing and adjacent areas through the resonance column test, Yuejun Lv, et al.\textsuperscript{[8]} has studied the soil in the Bo-hai sea bottom, Chunhua Shi\textsuperscript{[9]} has unfolded the Statistical analysis of dynamic parameters of silty clay soil in Beijing area. These testing data have played an important role in the practical application of engineering, but the studying data are still lacking in central regions(such as Beijing). Therefore, it is important to unford the studies on soil dynamic parameters in Beijing area.

The silty clay is most widely distributed soil type in Beijing area, with a buried depth ranging from 1 to 99 meters. Domestic scholars have studied the characteristics of silty clay in Beijing area.
however, sand distributed in 1-5 meters is seldom analyzed. Due to the particular characteristics of sand, the dynamic shear modulus and damping ratio are mainly based on the code of "Regulations for Seismic Safety Assessment of Engineering Sites (DB001-1994)". The code is out of date and the testing equipments are obsolete. The sand samples referred in the code are usually collected from all over China. The values of dynamic shear modulus and damping ratio could not well implied in Beijing. Therefore, it is necessary to carry out the dynamic-triaxial test of sand in Beijing and analyze the parameters of dynamic shear modulus and damping ratio. Due to the inhomogeneity of the sand, it is not easy to build the testing samples and the sandy silt is selected instead to conduct dynamic-triaxial tests.

2. Contents
Based on new technique and equipment, the sandy silt is conducted by dynamic-triaxial tests. Testing data are used to study the relationship between dynamic shear modulus and damping ratio with shear strain.

3. Program
The undisturbed sample of sandy silt are collected on site, and they are measured for soil name, clay content, moisture content, and density in soil laboratory. To study on relationship between dynamic shear modulus and damping ratio with shear strain, the dynamic-triaxial tests of sandy silt are conducted by DDS-70.

3.1. Testing theory
The DDS-70 is a static and dynamic-triaxial tests system by microcomputer controlled and electromagnetic, and it is produced by Beijing New Technology Institute. The system works by placing a cylindrical sample between the upper and lower pistons, Axial and lateral static pressures are applied to the sample by gas pressure. The electrical signal is converted to axial excitation forces by Exciter and Power amplifier, which is applied to the samples. The forces, displacements, and pore water pressures are recorded by measuring system, and it is analyzed by microcomputer system. The new dynamic-triaxial testing machines are shown in Figure 1.

![New Dynamic Triaxial Testing Machines](image)

**Figure 1.** New Dynamic Triaxial Testing Machines

3.2. Testing procedure
Before testing, the soil name, clay content, moisture content and density are first determined and the sandy silt samples are selected. A standard sample is rebuilt with a diameter of 39.1mm and a height of 80mm. The sandy silt sample is located between the upper and lower pistons of plastic vessel with consolidation ratio at 1.0 and confining pressure at 120MPa.

After consolidated, the dynamic and elastic testing is carried out under the undrained condition. The testing parameters are listed as follows, vibration frequency at 1.0Hz, cycles at 10, total vibration times at 200.
4. Testing analysis

4.1. Testing results

The relation between dynamic shear modulus and damping ratio with shear strain (Figure 2.) is obtained from testing data. Under the same confining pressure, the dynamic shear modulus of sandy silt is studied in a small shear strains. A better correlation curve is fitted. But due to the inhomogeneity of sandy silt, damping ratio indicated varies in a large range.

Figure 2. The curves of dynamic-shear modulus and damping ratio

4.2. Analysis of dynamic shear modulus

The trend is consistent with on dynamic shear modulus ratio of sandy silt under the same confining pressures, which is decreased with increase of shear strain. The dynamic shear modulus ratio is decreased slowly with shear strain between 0 and 0.0001. When it exceeds 0.0001, the dynamic shear modulus ratio is decreased quickly. This trend is consistent with the hysteresis on the stress-stains of sandy soil.

To confirm the rationality of testing results, the data obtained in the test is compared with the statistical data (the red curve in Figure 3.) by “BGI Engineering Consultants LTD” and the statistical curve (the blue curve in Figure 3.) of dynamic shear modulus of sands in Beijing area. The analysis shows that the testing data are distributed within the statistical curve and SEED curves. They have a good agreement with statistical curve in Beijing. The testing data are also compared with the statistical curve (the black curve in Figure 3.) of dynamic shear modulus of silty clay. It is shown that the testing curves of sandy silt are all under the statistical curve of silty clay. This is consistent with the hysteresis on dynamic characteristics of soils.
4.3. *Dynamic shear modulus calculating*

To obtain the dynamic shear modulus of sandy silt, the data are processed by averaging (removing the maximum and minimum, and averaging the surplus data, as shown in Table 1.). Compared with the Yuan’s results\(^{(11)}\), the relative-error range are all controlled at 5% or less. They have a good consistency and the testing results are reasonable.

**Table 1.** The data of dynamic-shear modulus

| γd  | 0.0000 | 0.0000 | 0.0000 | 0.0005 | 0.001  | 0.005  | 0.01   |
|-----|--------|--------|--------|--------|--------|--------|--------|
|     | 0.0005 | 1      | 5      |        |        |        |        |

| Sample | G/Gmax |       |       |       |       |       |       |
|--------|--------|-------|-------|-------|-------|-------|-------|
| sample 1 | 0.9928 | 0.9857 | 0.9322 | 0.8729 | 0.5783 | 0.4072 | 0.1208 |
| sample 2 | 0.9923 | 0.9847 | 0.9279 | 0.8656 | 0.5629 | 0.3917 | 0.1141 |
| sample 3 | 0.9901 | 0.9821 | 0.9223 | 0.8546 | 0.5432 | 0.3564 | 0.0876 |
| sample 4 | 0.9878 | 0.9792 | 0.9157 | 0.8394 | 0.5027 | 0.3353 | 0.0972 |
| sample 5 | 0.9843 | 0.9771 | 0.9021 | 0.8075 | 0.4258 | 0.2987 | 0.0711 |
| sample 6 | 0.9886 | 0.9774 | 0.8963 | 0.8121 | 0.4637 | 0.3018 | 0.0796 |
| Teating results | 0.9893 | 0.9810 | 0.9161 | 0.8420 | 0.5128 | 0.3485 | 0.0951 |
| Yuan’s results\(^{(11)}\) | 0.9928 | 0.984 | 0.9187 | 0.8485 | 0.5263 | 0.3568 | 0.0998 |
| error(%) | -0.35 | -0.30 | -0.28 | -0.76 | -2.57 | -2.32 | -4.74 |

5. **Conclusion**

(1) The same trend on dynamic shear modulus ratio of sandy silt is demonstrated under the same confining pressures. It decreases with increase of shear stain. This negative correlation trend is consistent with the hysteresis on the stress-stains of sandy soil.
(2) The comparison between the testing data with statistical data and curve shows that the testing curves are closer to statistical data in Beijing.

(3) The data are processed by averaging, and compared. The relative-error is acceptable. The testing results are considered to be reasonable.

(4) Disturbance of soils on selection, preparation and testing leads to the unevenness of soils. A large range of damping ratio is shown, and none of regularity curves are obtained. Currently, resonant-column testing has been carried out to reveal the statistical relation between damping ratio and shear stain.

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