The development law of pore water pressure of the hydraulic fill subgrade in Shanghai under traffic vibratory load

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ABSTRACT

The development law of pore water pressure in the roads of the hydraulic fill area under traffic vibratory load was analyzed by dynamic triaxial test in this paper. The test results show that pore water pressure of hydraulic fill subgrade under traffic vibratory load increases with vibration times. At the beginning of vibration, the pore water pressure increases quite quickly. The development law of pore water pressure of hydraulic fill subgrade differs in lower and higher frequency traffic vibratory load. The development law of pore water pressure under lower and higher frequency traffic vibratory load can be described by Eq. 1 and Eq. 2, respectively. When the pore water pressure reaches ninety percent of effective value of confining pressure, the deformation failure of hydraulic fill under higher frequency traffic vibratory load occurs.

RÉSUMÉ

Dans ce mémoire, un essai dynamique triaxial est exécuté pour rechercher la loi de développement de la pression interstitielle dans le remblai hydraulique due aux vibrations des véhicules. Les résultats montrent que : premièrement la pression interstitielle croit avec l'augmentation de la fréquence de vibration. Deuxièmement, la pression interstitielle augmente plus rapidement au début de l'excitation. De plus, la loi de développement de la pression interstitielle diffère selon la fréquence de vibration. Les lois du développement de la pression interstitielle selon la basse et la haute fréquence sont décrites respectivement en utilisant la formule 1 et la formule 2. Enfin, lorsque la pression interstitielle atteind 90% de la pression efficace de confinement, le remblai commence à s'écrouler.

1 INTRODUCTION

Most area of Shanghai Newport Town is the fresh hydraulic fill, with the thickness from 6 m to 8 m, and the underground water table is about 1 m. Due to poor engineering property of the hydraulic fill, deformation is obvious under the traffic vibratory load (especially under heavy trucks), a considerable part of the road subgrade and building foundation have suffered from subgrade settlement, crack or failure, which has greatly affected the construction pace of Shanghai Newport Town. How to avoid engineering geological disaster caused by deformation and failure (liquefaction) of the hydraulic fill subgrade under traffic vibratory load is a difficult problem in road construction of the hydraulic fill area.

The deformation of the hydraulic fill is attributed to two factors. One is that drain consolidation results in deformation and settlement of the stratum; the other is that the soil mass of the road subgrade generates irrecoverable deformation under traffic vibratory load, makes the residual pore water pressure gradually accumulate until the shear strength of the soil mass is zero and the soil mass liquefy(Boulanger and Seed, 1995 ;Talaganov,1996; Staroszczyk,1996; Zhou and Wang, 2002). The pore water pressure plays an important role in liquefaction failure of soil mass. The change law of pore water pressure of sand soil under the dynamic load was analyzed (Zeng, et al.,2002; Zhu, et al.,2003; Meng, et al.,2005; Zhang,2005). The development law of pore water pressure of saturated soft clay under the dynamic load was analyzed (Lei, et al.,2001; Bai,2003). And the effect of initial consolidation condition on the development law of pore water pressure was studied (Guo,et al.,2004; Wang, et al.,2005).

Due to special formation mode of the hydraulic fill, researchers used to pay little attention to hydraulic fill. The knowledge about dynamic characteristic of hydraulic fill under traffic vibratory load is not clear. So it is necessary to study the dynamic characteristic of hydraulic fill under traffic vibratory load. In this paper, the dynamic triaxial test were applied to simulate the traffic vibratory load (Tang, et al.,2004; Guan, et al., 2004), and the development law of pore water pressure of hydraulic fill subgrade under traffic vibratory load was analyzed.

2 PROPERTIES OF THE HYDRAULIC FILL

The hydraulic fill (also called the dredger fill) is the sediment soil formed by hydraulic filling mud and sand. Table1 shows the physical properties of the hydraulic fill.

Table 1. Physical properties of the hydraulic fill

Water content (%)	Density (g/cm^3)	Weight	Pore ratio
27.2	1.92	2.70	0.79

3 TEST PLAN

3.1 Specimen Preparation

The specimen was the undisturbed soil specimen of the hydraulic fill area in Shanghai Newport Town. The specimen was prepared completely according to the preparation procedure of GDS. The specimen was 140 mm high and the diameter is 70 mm. The specimen was saturated by the reverse pressure, and reached saturation when the parameter B of pore water pressure was over 0.98.

3.2 Test parameters

The test was carried out at the same amplitude and consolidation ratio, different vibratory frequencies. The coefficient of side pressure K_0 was 0.45 according to the geotechnical test, so the consolidation ratio of the hydraulic fill was set 2.2. Through the statistic survey, the most popular loading truck in research area was 20-tonned truck, so the 20-tonned truck was chosen as the simulated object. Calculations showed that the acting force of the 20-tonned truck for the subgrade 4 m deep was close to 0.002 KN, so the amplitude of the dynamic triaxial test was set 0.002 KN. The statistic result of the traffic flow showed that the most cycle of the traffic action was between 0.5 s and 5 s. Therefore, the frequency chose 0.2 Hz and 2.5 Hz.

3.3 Failure Standard of Test

As for the study on liquefaction of sand and silt, research data showed that the failure standard was that the pore water pressure reached the effective value of confining pressure or the axial strain reached 5%. In this test, the latter was applied to the hydraulic fill test.

4 ANALYSIS OF THE TEST RESULT AND DISCUSS

4.1 Development law of pore water pressure

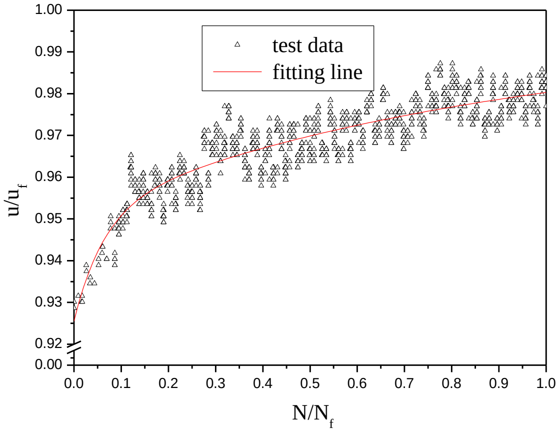

Figure 1. Relation curve between u/u_f and N/N_f under 0.2 Hz

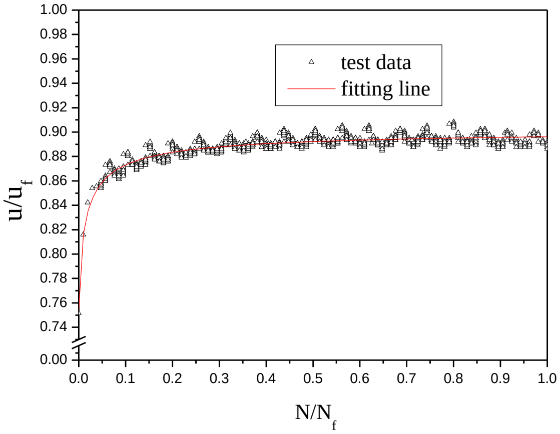

Figure 2. Relation curve between u/u_f and N/N_f under 2.5 Hz

Figure 1 and Figure 2 present the relation between vibration times and the pore water pressure of the hydraulic fill. In Figure 1 and Figure 2, N represents the vibration times, N_f represents vibration times in case of the specimen's failure (when the specimen is liquefied). u represents the value of pore water pressure, u_f represents the effective value of confining pressure.

Figure 1 shows that the pore water pressure increases quickly at the beginning of vibration. After the vibration frequency ratio reaches 0.2, the pore water pressure increases slowly until up to failure of the specimen. When the pore water pressure ratio reaches 0.98, the specimen is failed. The development law of pore water pressure can be fitted by ExpAssoc model as follows:

$$u/u_f = a + b_1 \bullet (1-e^{-(\frac{N}{N_f}/t_1)}) + b_2 \bullet (1-e^{-(\frac{N}{N_f}/t_2)}) \qquad [1]$$

Where a, b_1, t_1, b_2, t_2 are fitting parameters. The value of parameters is shown Table 2.

Table 2. Fitting parameters

f /Hz	a	b_1	t_1	b_2	t_2	R^2
0.2	0.9255	0.0426	0.8965	0.0262	0.0634	0.8027

Figure 2 shows that when the vibration frequency is 2.5 Hz, the pore water pressure sharply increases at the beginning of vibration, and the pore water pressure increases slowly after the vibration ratio reaches 0.1. When the pore water pressure ratio reaches 0.90, the specimen is failed. The development law of pore water pressure is in accord with the Logistic model as follows:

$$u / u_f = a_2 - \frac{a_2 - a_1}{1 + (b\frac{N}{N_f})^c} \quad [2]$$

Where a_1, a_2, b, c are fitting parameters. The value of parameters is shown Table 3.

Table 3. Fitting parameters

f /Hz	a_1	a_2	b	c	R^2
2.5	0.7539	0.9024	64.7668	0.7493	0.7975

Figure 1 and Figure 2 show that the fitted curve is in good match with the test data. So the development law of pore water pressure in hydraulic fill subgrade under the lower and higher frequency traffic vibratory load can be described by Eq. 1 and Eq. 2, respectively.

4.2 Discussion

Why is there difference in development law of pore water pressure between lower and higher frequency? The soil mass will generate the irrecoverable deformation duo to the traffic vibratory load, which makes the residual pore water pressure of the soil mass gradually accumulate and the pore water pressure increase. When the vibration frequency is lower, the pore water pressure has a relative long dissipation time, the residual pore water pressure between two vibrations is relative smaller, so increase of pore water pressure is quite slow; when vibration frequency is higher, the pore water pressure has a relative short dissipation time, the residual pore water pressure between two vibrations is relative bigger, so increase of pore water pressure is quick.

In both case, when the pore water pressure is close to the value of effective confining pressure, increase of the pore water pressure is relative slow, which show that the failure of hydraulic fill subgrade under traffic vibratory load is a long process. When the specimens are failed, the pore water pressure of specimen under lower and higher frequency traffic vibratory load reached 0.98 and 0.90, respectively. So it is not suitable for hydraulic fill to regard pore water pressure reaching the effective value of confining pressure as the failure standard. The pore water pressure reaching ninety percent of effective value of confining pressure is recommended as the failure standard of hydraulic fill in research area under traffic vibratory load. In order to prevent occurrence of deformation and failure (liquefaction) of the hydraulic fill, some effective measures should be taken to dissipate pore water pressure of the hydraulic fill under traffic vibratory load.

5 CONCLUSIONS

With the same vibration amplitude, the development law of pore water pressure of the hydraulic fill subgrade differs in lower and higher frequency traffic vibratory load. The development law of pore water pressure under lower and higher frequency traffic vibratory load can be fitted by Eq. 1 and Eq. 2, respectively.

The pore water pressure reaching ninety percent of effective value of confining pressure is recommended as the failure standard of hydraulic fill in research area under traffic vibratory load.

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