
Research on Pore Water Pressure of Saturated Muck Soil Under Traffic Loading of Low Frequency

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Abstract: In order to study the pore water pressure of saturated muck soil under traffic loading of low frequency in Pearl River Delta, the influence of loading frequency, cyclic stress and consolidation on pore water pressure are analyzed. The results show that the final pore water pressure is increased as the frequency decreases, but the increasing rate of pore water pressure is periodical. Moreover, isotropic consolidation can improve the effective stress of soil and slow down the development of pore water pressure, but it is not the key factor. The key factor of influencing the pore water pressure is the cyclic stress, the following is loading frequency, and the consolidation is the last one. In the end, considering cyclic stress, loading frequency and consolidation, a model of pore water pressure based on a math model is built up.

Keywords: Muck Soil, Low Frequency, Traffic Load, Pore Water Pressure, Pore Pressure Model

1. Introduction

Multiple urban agglomeration are lied in the east coast of China. The transportation network supports the development of the whole city, however, the high moisture content, void ratio and poor structural soft clay brings difficulties to the roads and subways construction. In addition, there are many factors affecting the development of dynamic pore water pressure of soft clay under traffic load, like cyclic stress, loading frequency, cyclic numbers, stress history and stress path, etc. There were some tests [1, 2] showed that when the loading frequency is limited, the lower the frequency is, the higher the cumulative plastic strain and pore pressure of soil develop. However, there were some scholars such as Ansal [3] showed that the influence of loading frequency only work at the beginning of the loading stage which can be ignored when the soil samples are closed to broken. Yasuhara [4] suggested that the influence of frequency on the acumulative plastic strain can be almost negligible. Zhang Ru [5] did a dynamic triaxial test on saturated clay soil, which showed that the influence of the frequency f on dynamic characteristics of soft soil worked periodically during the frequency f is from 0.1 Hz ~ 0.4 Hz. Wei

Xinjiang [6] suggested that the pore water pressure develop slowly if the consideration degree become lower. Wang Jun [7] showed that the development of pore water pressure is not obvious when the loading frequency is less than 1 Hz. Wang Yuandong [8] suggested that the pore water pressure of reinforced soil decrease as the cell pressure increase. Ding Zhi [9] showed that the law of pore water pressure in un-drained condition is similar to the drained condition. Zhao Chunyan [10] built a model of accumulative pore water pressure considering cyclic numbers, deviatoric stress and the consolidation. The experiments above showed that there are many factors influencing the development of pore water pressure. This paper, firstly, summarize the previous research, and then analyze the dates by amounts of dynamic triaxial tests for the Pearl River Delta saturated muck soil under traffic loading of low frequency, which is to study the influence of the cyclic stress, loading frequency and the consolidation on the pore water pressure. In the end, a model of pore water pressure is established.

2. The Dynamic Triaxial Test of Saturated Muck Soil Under Traffic Loading of Low Frequency

2.1. Experiment Apparatus and Soil Sample

A dynamic test of saturated muck soil is carried out by GCTS SPAX-2000 (modified) static and dynamic true triaxial testing system which is developed and manufactured by United States. The system consists of seven sub-systems: (1) SPAX-100 true triaxial pressure chamber; (2) PCP-2000-H pressure control panel; (3) PVC-25-HC confining pressure / volume computer servo controller; (4) PVC-200-HP back pressure / pore-pressure volume controller; (5) SCON-2000 digital servo controller and acquisition system; (6) HPS-10-5 variant constant pressure pump; (7) WIN -CATS-ADV control and post-processing software. The entire testing process is controlled by integrated computer software named GDSLAB that can collect and deal with the data to emulate a partial stress and cyclic stress traffic load.

The soft soil sample was taken from Shenzhen Baoan Airport, which is in offshore sea level 12m~15m. It contains mica, quartz and shell debris. The moisture content and compressibility are high and the permeability is poor. Basic physical and mechanical properties of samples are shown in Table 1.

Table 1. Physical and mechanical properties of soft clay.

$\rho/g/cm^3$	w/%	e	I_L	I_p	d_s
1.63	63.4~65.2	1.57	0.98	27.9	2.71

2.2. Testing Program

Isotropic and anisotropic consolidation are took in this experiment. The frequency are 0.1Hz, 0.25Hz, 0.5Hz and 1 Hz. The cyclic stress are 20 kPa, 50 kPa and 65kPa. The test program is shown as Table 2. $\epsilon_d=15\%$ is the failure standard. If the soil sample did not fail, the sample would be shear by 0.01%/min until broken. In order to simulate actual operation, firstly, the drain valve is going to be closed before dynamic loading. And then the initial static deviator stress is loaded, which is half of dynamic stress.

Table 2. Un-drained cyclic triaxial test parameters.

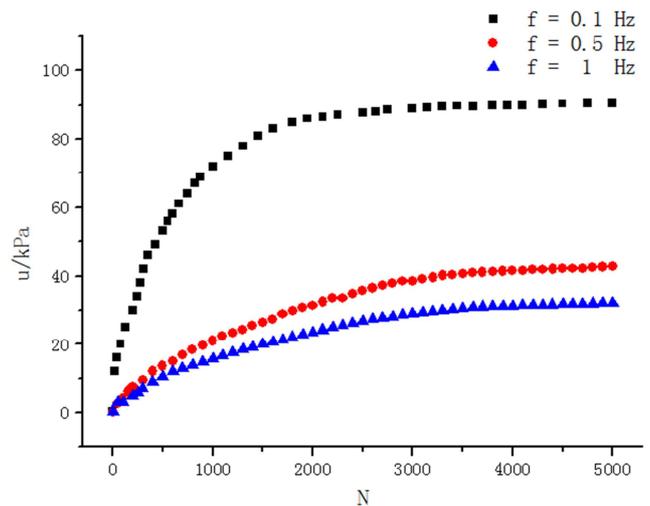
Test Number	Intermediate Principal Stress σ_2 /kPa	Frequency f/Hz	Dynamici Stress σ_d /kPa
C-1	200	0.1	20
C-2	200	0.5	20
C-3	200	1	20
C-4	200	0.1	50
C-5	200	0.5	50
C-6	200	1	50
C-7	200	0.1	65
C-8	200	0.5	65
C-9	200	1	65
C-10	225	0.1	20
C-11	225	0.5	20

Test Number	Intermediate Principal Stress σ_2 /kPa	Frequency f/Hz	Dynamici Stress σ_d /kPa
C-12	225	1	20
C-13	225	0.1	50
C-14	225	0.5	50
C-15	225	1	50
C-16	225	0.1	65
C-17	225	0.5	65
C-18	225	1	65
C-19	250	0.1	20
C-20	250	0.5	20
C-21	250	1	20
C-22	250	0.1	50
C-23	250	0.5	50
C-24	250	1	50
C-25	250	0.1	65
C-26	250	0.5	65
C-27	250	1	65
C-28	200	0.25	20
C-29	200	0.25	50
C-30	250	0.25	50

3. Test Result and Analysis

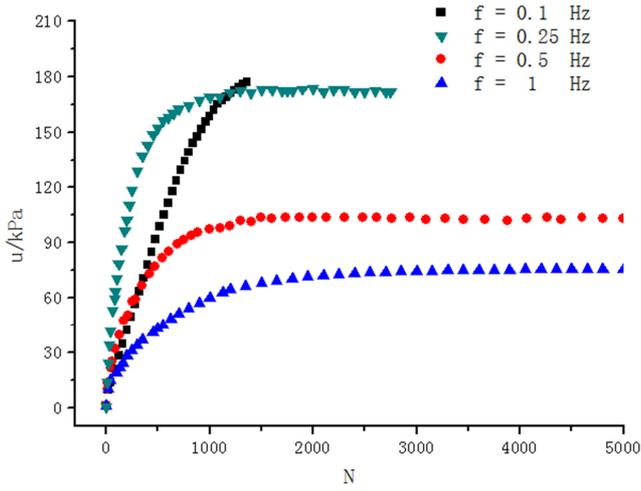
3.1. The Law of Super Pore Water Pressure Under Different Frequencies

The curves of the relationship between super pore water pressure u and cyclic number N under different frequency of the same dynamic stress and isotropic consolidation $\sigma_1'=\sigma_2'=\sigma_3'=200kPa$ are shown in Figure 1, 2, 3. The curves of the relationship between super pore water pressure u and cyclic number N under different frequency of the same dynamic stress and anisotropic consolidation $\sigma_1'=\sigma_2'=225kPa, \sigma_3'=200kPa$ are shown in Figure 4, 5, 6. The curves of the relationship between super pore water pressure u and cyclic number N under different frequency of the same dynamic stress and anisotropic consolidation $\sigma_1'=\sigma_2'=250kPa, \sigma_3'=200kPa$ are shown in Figure 7, 8, 9.



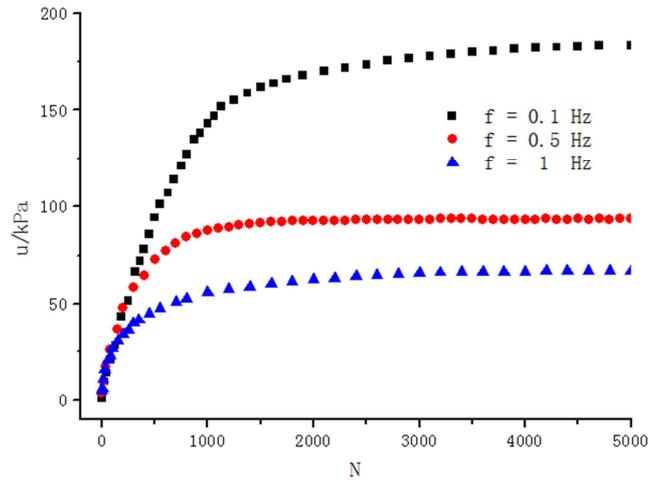
Effective stress $\sigma_1'=\sigma_2'=\sigma_3'=200kPa$, dynamic stress $\sigma_d=20kPa$

Figure 1. Super Pore Water Pressure u against Cyclic Number N .



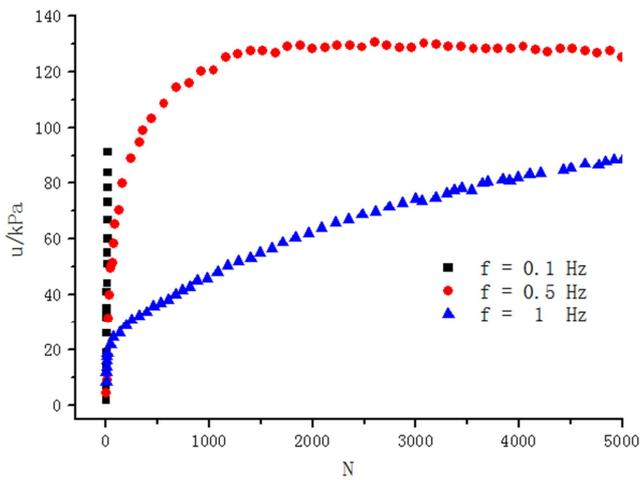
Effective stress $\sigma_1'=\sigma_2'=\sigma_3'=200\text{kPa}$, dynamic stress $\sigma_d=50\text{kPa}$

Figure 2. Super Pore Water Pressure u against Cyclic Number N .



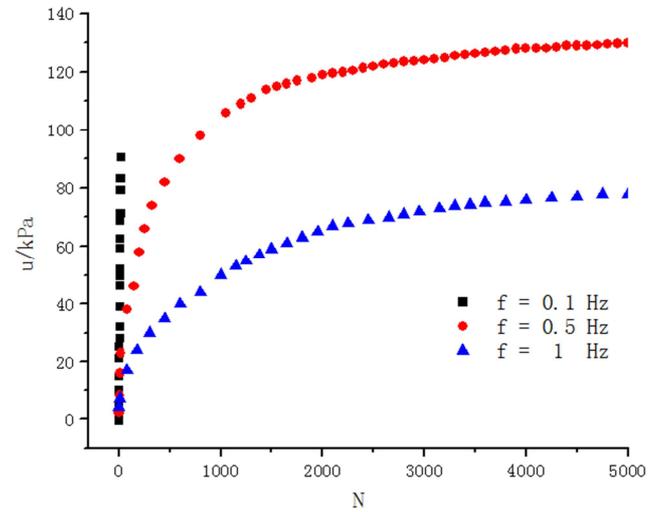
Effective stress $\sigma_1'=\sigma_2'=225\text{kPa}$, $\sigma_3'=200\text{kPa}$, dynamic stress $\sigma_d=50\text{kPa}$

Figure 5. Super Pore Water Pressure u against Cyclic Number N .



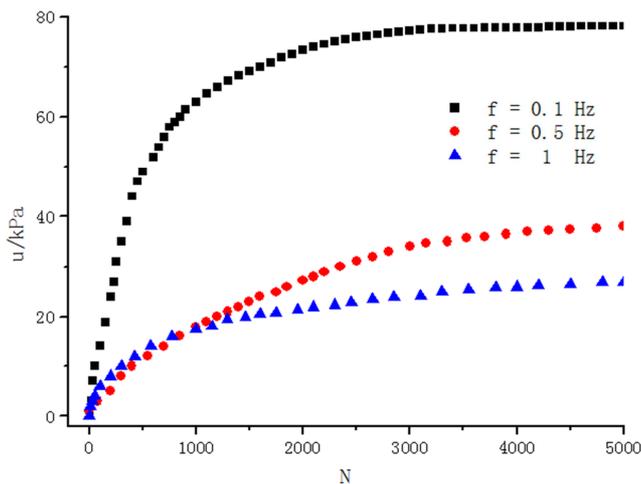
Effective stress $\sigma_1'=\sigma_2'=\sigma_3'=200\text{kPa}$, dynamic stress $\sigma_d=65\text{kPa}$

Figure 3. Super Pore Water Pressure u against Cyclic Number N .



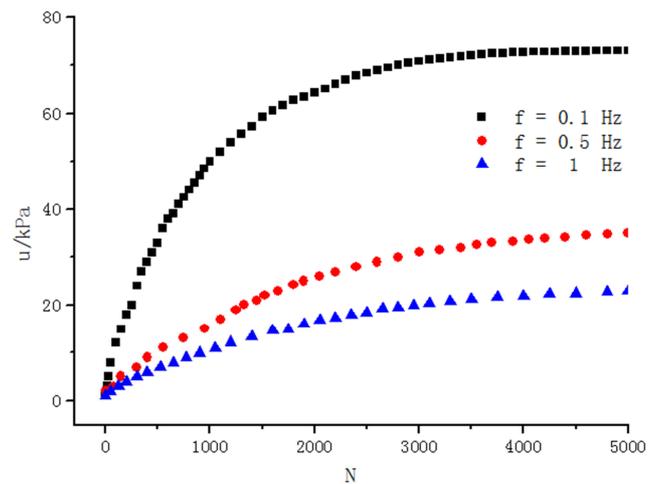
Effective stress $\sigma_1'=\sigma_2'=225\text{kPa}$, $\sigma_3'=200\text{kPa}$, dynamic stress $\sigma_d=65\text{kPa}$

Figure 6. Super Pore Water Pressure u against Cyclic Number N .



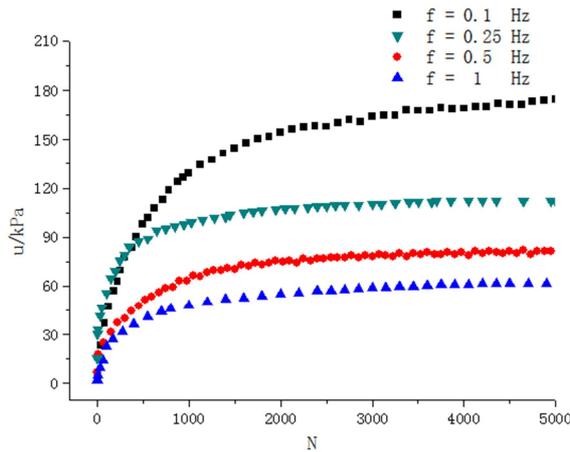
Effective stress $\sigma_1'=\sigma_2'=225\text{kPa}$, $\sigma_3'=200\text{kPa}$, dynamic stress $\sigma_d=20\text{kPa}$

Figure 4. Super Pore Water Pressure u against Cyclic Number N .



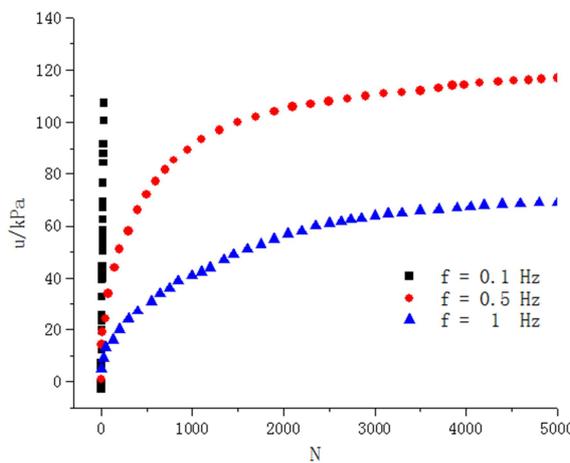
Effective stress $\sigma_1'=\sigma_2'=250\text{kPa}$, $\sigma_3'=200\text{kPa}$, dynamic stress $\sigma_d=20\text{kPa}$

Figure 7. Super Pore Water Pressure u against Cyclic Number N .



Effective stress $\sigma_{1,2}'=250kPa$, $\sigma_3'=200kPa$, dynamic stress $\sigma_d=50kPa$

Figure 8. Super Pore Water Pressure u against Cyclic Number N .



Effective stress $\sigma_1'=\sigma_2'=250kPa$, $\sigma_3'=200kPa$, dynamic stress $\sigma_d=65kPa$

Figure 9. Super Pore Water Pressure u against Cyclic Number N .

Since this soil samples are taken from the offshore plane following 13m~16m which lead to that the moisture content is higher than 63% generally, some of them are as high as 68%, which result in that the dynamic property is poorer than common clay. The effective stress of the sample was still lower than the similar saturated clay under the same condition even after 96 hours solidifying. Therefore the majority of energy is undertaken by pore water of the soil body during the initial period loading. No matter the growth or the final value of pore-water pressure are, this soil sample is faster and higher than the common saturated clay, which is shown in Figure 1~9.

Figure 1 shows the change of the super pore water pressure of the soil sample which is consolidated after 200kPa and then loaded by different frequencies and dynamic stress of 20kPa. Taking the 0.1Hz for example, in the initial loading period (the cyclic numbers are about 2000), the energy is mainly undertaken by the soil body and the pore water, therefore the pore water pressure rapidly grows and reaches as high as 77% of the limiting super pore water pressure. Along with the soil body compacting and the particles between the pore reducing gradually, the main pore water is

working and the pore water pressure's growing rate slows down obviously. And then the pore water pressure gradually becomes stable and stay in a stage which it almost does not grow. That is called the limiting value of the pore-water pressure, which is the 45% of the effective confining pressure. Generally, the growth of the super pore water pressure can be summarized as three stages---rapid growth, slow growth and gradual staying, which is similar to the study result of the saturated soft soil around tunnel under cyclic loading by Tang Yiqun [13].

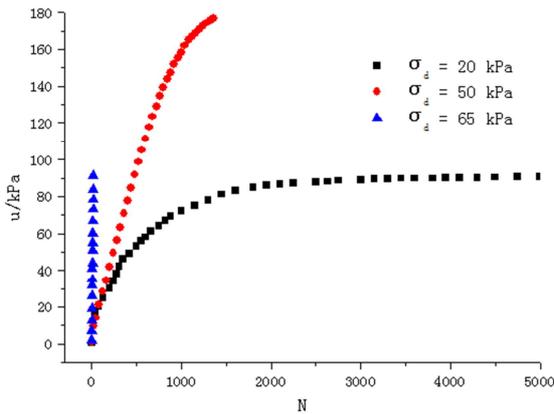
The comparison of super pore pressure water of 50kPa under 0.1Hz, 0.25Hz, 0.5Hz and 1Hz is shown in Figure 2. Comparing to the 20kPa, the final pore water pressure of 50kPa is higher than the former. That is because the higher the cyclic stress is, the higher energy impacting to the soil, which leads to that the higher energy can be absorbed by pore water under the same condition. Comparing to the 0.1Hz and 0.25Hz, although the final pore water pressure of 0.25Hz is closed to 0.1Hz, which presents that the influence of frequency on the final pore water pressure is weaken when the frequency is low enough, the increasing rate of 0.25Hz is still larger than 0.1Hz, which is closed to the result of Yasuhara [4], a study showing that the higher the frequency is, the higher the increasing rate of pore water pressure become. However, when the frequency is larger than 0.25Hz, the growth of the pore water is closed to the viewpoint of most scholars, like Wang Jun and Zhou Nianqing [11, 12], which suggested that the lower the frequency is, the higher the increasing rate of pore water pressure and the higher final pore water pressure become. This results from that lower frequency means the more time of the load working on soil body. The more energy on the soil are, the higher the final pore water pressure become since the pore water pressure become accumulative gradually and can not dissipated quickly under the same loading frequency. Therefore under the low frequency cyclic loading, the increasing rate of the pore water pressure of saturated muck soil appears periodical. During the frequency of 0.1Hz~0.25Hz, the relationship between frequency and the pore water pressure is related, namely that the higher the loading frequency is, the higher the increasing rate of pore water pressure become. However, between the frequency of 0.25Hz~1Hz, the relationship between frequency and the pore water pressure is negative, namely the higher the frequency is, the lower the increasing rate of the pore water pressure become.

Figure 3, 6, 9 shows the change of the pore water pressure of cyclic stress 65kPa under different consolidation stresses. The increasing type of the pore water pressure is the rapidly rising under 0.1Hz, which presents that the pore water pressure keep an high increasing rate until the soil to be broken from the beginning of the load to the end. According to the information above, the rapidly rising type of pore water pressure mostly happens in low frequency and high cyclic stress. The type of stable mostly happens in high frequency and low cyclic stress. And the type of gradually growing is the transitional stage between type of rapidly rising and stable.

Figure 8 shows that how the pore water pressure grow during different frequency, like 0.1Hz, 0.25Hz, 0.5Hz and 1Hz, which is different to the result above. The final pore water pressure do not increase largely as the frequency, but grow slowly after 0.5Hz. That suggests that there is an threshold of frequency between 0.1Hz~1Hz, leading to the type changing of how the pore water pressure increase. The increasing rate of pore water pressure slow down when the experimental frequency is higher than the threshold.

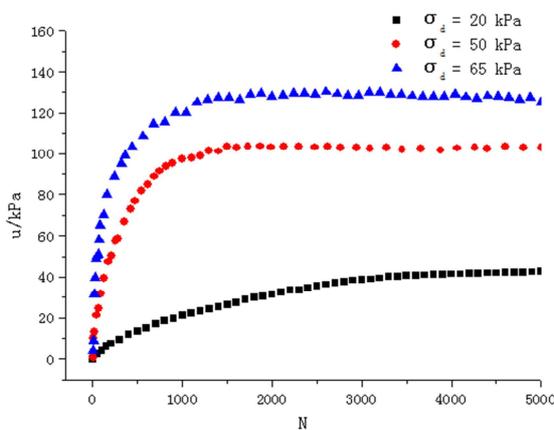
3.2. The Law of Super Pore Water Pressure Under Different Dynamic Stress

The curves of the relationship between super pore water pressure u and cyclic number N under different dynamic stress of the same frequency and isotropic consolidation $\sigma_1'=\sigma_2'=\sigma_3'=200\text{kPa}$ are shown in Figure 10, 11, 12. The curves of the relationship between super pore water pressure u and cyclic number N under different dynamic stress of the same frequency and anisotropic consolidation $\sigma_1'=\sigma_2'=225\text{kPa}$, $\sigma_3'=200\text{kPa}$ is shown in Figure 13, 14, 15. The curves of the relationship between super pore water pressure u and cyclic number N under different dynamic stress of the same frequency and anisotropic consolidation $\sigma_1'=\sigma_2'=250\text{kPa}$, $\sigma_3'=200\text{kPa}$ are shown in Figure 16, 17, 18.



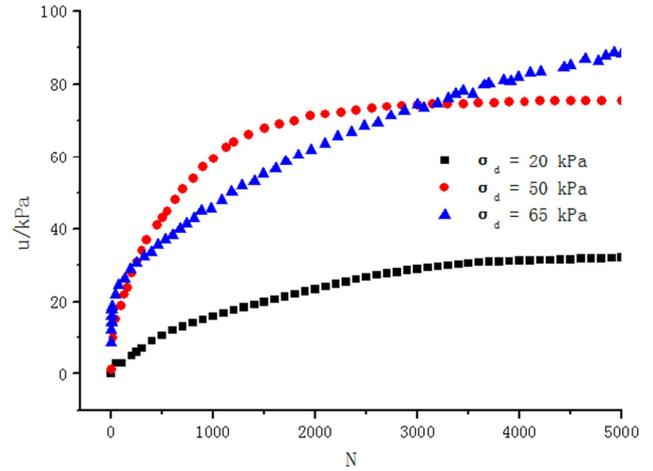
Effective stress $\sigma_1'=\sigma_2'=\sigma_3'=200\text{kPa}$, loading frequency $f=0.1\text{ Hz}$

Figure 10. Super Pore Water Pressure u against Cyclic Number N .



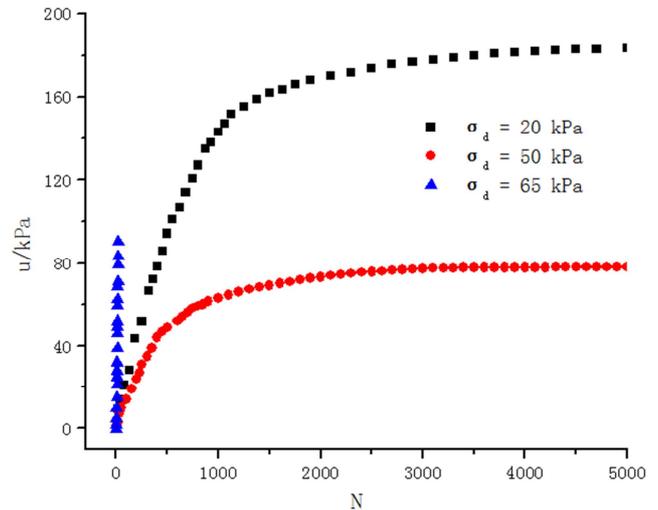
Effective stress $\sigma_1'=\sigma_2'=\sigma_3'=200\text{kPa}$, loading frequency $f=0.5\text{ Hz}$

Figure 11. Super Pore Water Pressure u against Cyclic Number N .



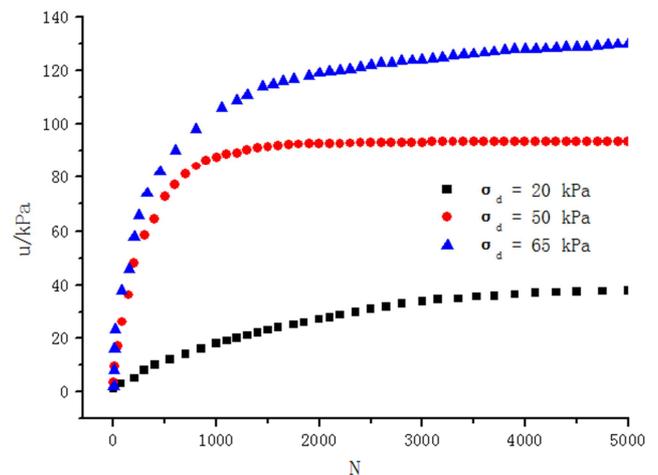
Effective stress $\sigma_1'=\sigma_2'=\sigma_3'=200\text{kPa}$, loading frequency $f=1\text{ Hz}$

Figure 12. Super Pore Water Pressure u against Cyclic Number N .



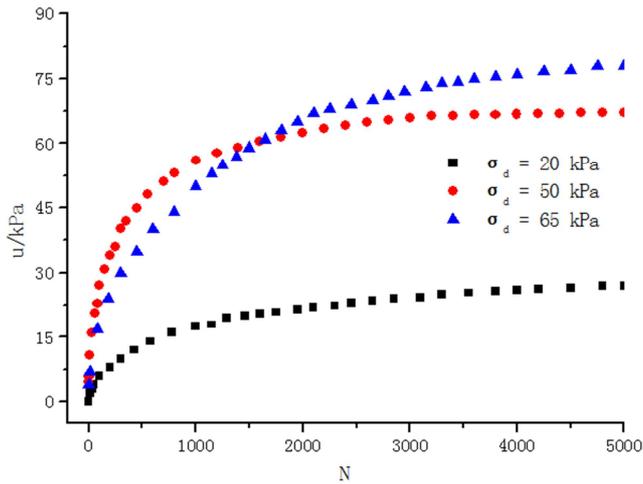
Effective stress $\sigma_1'=\sigma_2'=225\text{kPa}$, $\sigma_3'=200\text{kPa}$, loading frequency $f=0.1\text{ Hz}$

Figure 13. Super Pore Water Pressure u against Cyclic Number N .



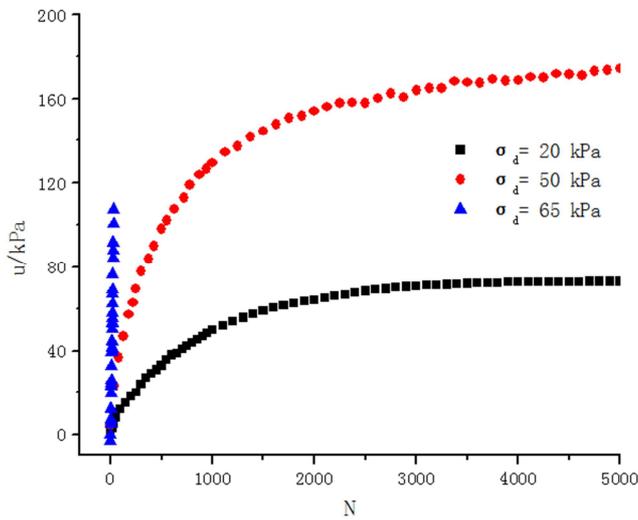
Effective stress $\sigma_1'=\sigma_2'=225\text{kPa}$, $\sigma_3'=200\text{kPa}$, loading frequency $f=0.5\text{ Hz}$

Figure 14. Super Pore Water Pressure u against Cyclic Number N .



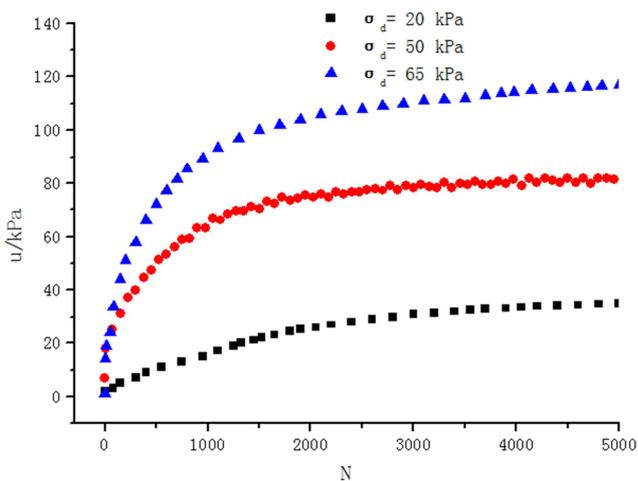
Effective stress $\sigma_1'=\sigma_2'=225\text{kPa}$, $\sigma_3'=200\text{kPa}$, loading frequency $f=1\text{ Hz}$

Figure 15. Super Pore Water Pressure u against Cyclic Number N .



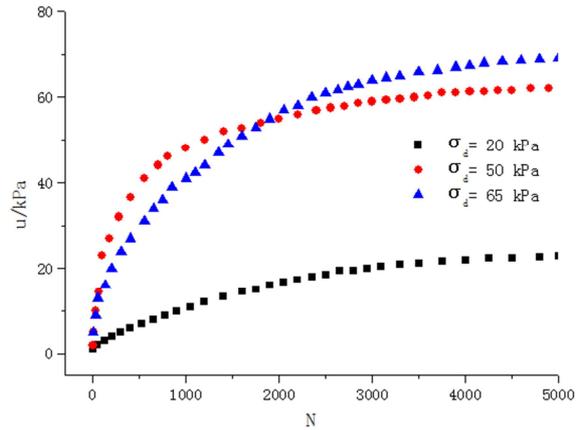
Effective stress $\sigma_1'=\sigma_2'=250\text{kPa}$, $\sigma_3'=200\text{kPa}$, loading frequency $f=0.1\text{ Hz}$

Figure 16. Super Pore Water Pressure u against Cyclic Number N .



Effective stress $\sigma_1'=\sigma_2'=250\text{kPa}$, $\sigma_3'=200\text{kPa}$, loading frequency $f=0.5\text{ Hz}$

Figure 17. Super Pore Water Pressure u against Cyclic Number N .



Effective stress $\sigma_1'=\sigma_2'=250\text{kPa}$, $\sigma_3'=200\text{kPa}$, loading frequency $f=1\text{ Hz}$

Figure 18. Super Pore Water Pressure u against Cyclic Number N .

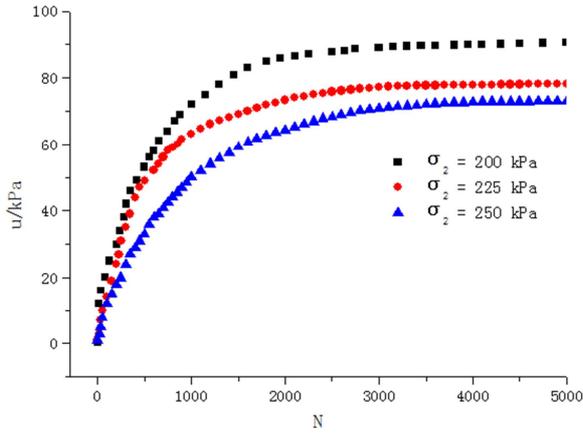
The curve of the relationship between super pore water pressure u and cyclic number N of different cyclic stress under 0.1Hz and the isotropic consolidation is shown in Figure 10, which presents that the higher cyclic stress is, the higher increasing rate of the pore water pressure become. That is because higher cyclic stress presents more energy working on the soil body. Since the construction of saturated muck soil is poorer than common soil clay, most energy is maintained by the soil pore, which leads to the pore water increasing rapidly. In addition, considering the failure standard is 15%, the final pore water pressure of 65kPa is lower than 50kPa, which means the final pore water pressure is not proportional to the cyclic stress, since there is not enough time for the pore water pressure to increase when the energy loading on the soil body is too great. So the experimental cyclic stress should be less than 50kPa if requiring to study the development of pore water pressure under 0.1Hz according the experimental result.

Even most studies [1~6] show that the higher the cyclic stress are, the quicker the increasing rate of pore water pressure develop, but this is based on a limited cyclic numbers and cyclic stress. Figure 12, 15, 18 show that the instant pore water pressure of 50kPa is higher than 65kPa under the cyclic numbers of 0~2000, which presents that the development of pore water pressure do not follow the rule that the higher the cyclic stress is, the higher the increasing rate of pore water pressure become since the higher cyclic stress are, the quicker for the balance between effective stress and pore water pressure break. However, when the cyclic numbers are larger than 5000, the final pore water pressure still increase as the cyclic stress increase since the more energy of the pore absorb, the higher the final pore water pressure increase.

3.3. The Law of Super Pore Water Pressure Under Different Dynamic Stress

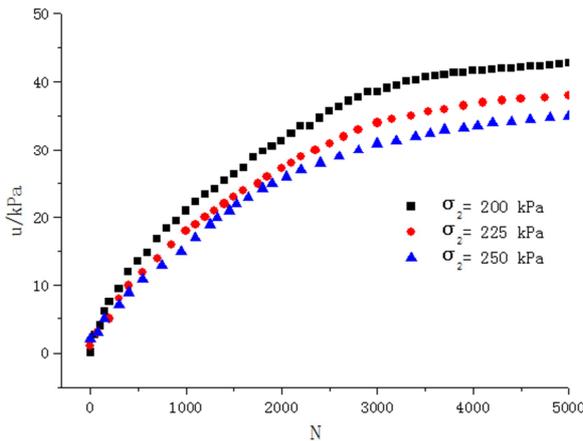
The curves of the relationship between super pore water pressure u and cyclic number N of different consolidation, the same dynamic stress and frequency are shown in Figure 19, 20, 21. The curves of the relationship between super pore

water pressure u and cyclic number N of different consolidation, the same dynamic stress and frequency are shown in Figure 22, 23, 24. The curves of the relationship between super pore water pressure u and cyclic number N of different consolidation, the same dynamic stress and frequency are shown in Figure 25, 26, 27.



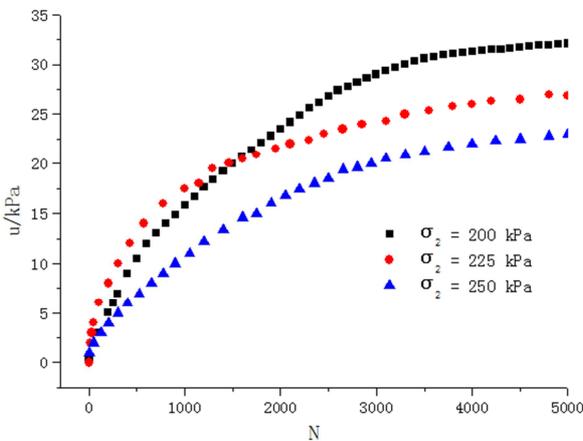
Loading frequency $f = 0.1$ Hz, dynamic stress $\sigma_d = 20$ kPa

Figure 19. Super Pore Water Pressure u against Cyclic Number N .



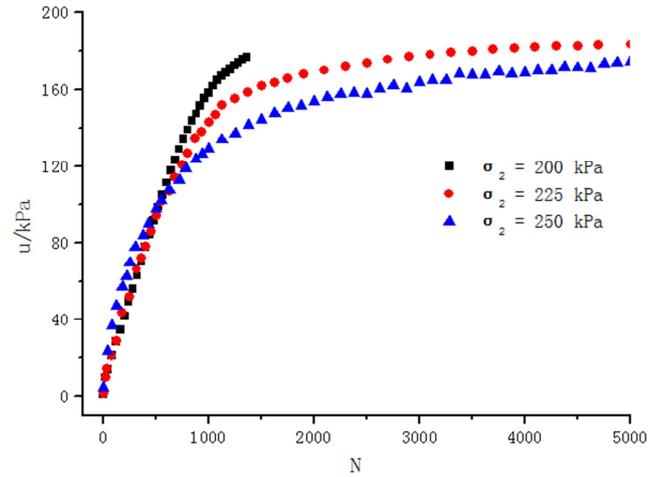
Loading frequency $f = 0.5$ Hz, dynamic stress $\sigma_d = 20$ kPa

Figure 20. Super Pore Water Pressure u against Cyclic Number N .



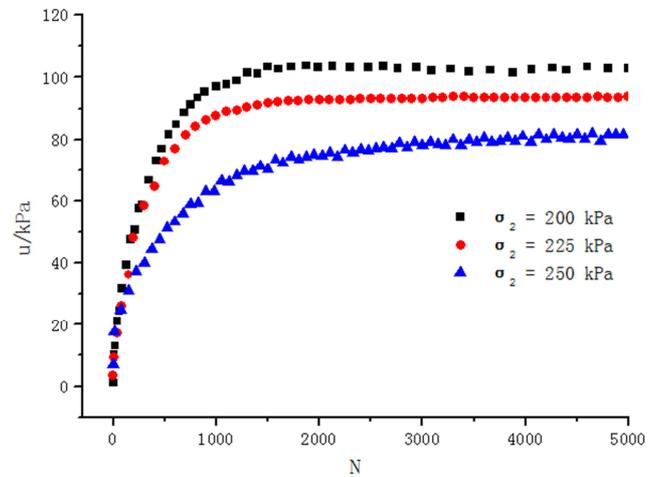
Loading frequency $f = 1$ Hz, dynamic stress $\sigma_d = 20$ kPa

Figure 21. Super Pore Water Pressure u against Cyclic Number N .



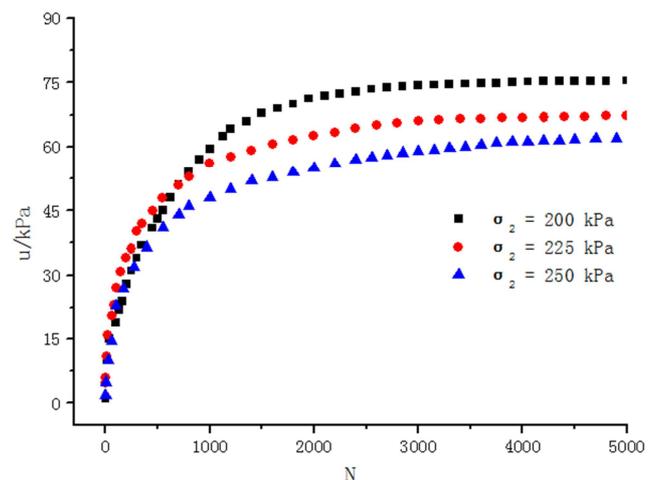
Loading frequency $f = 0.1$ Hz, dynamic stress $\sigma_d = 50$ kPa

Figure 22. Super Pore Water Pressure u against Cyclic Number N .



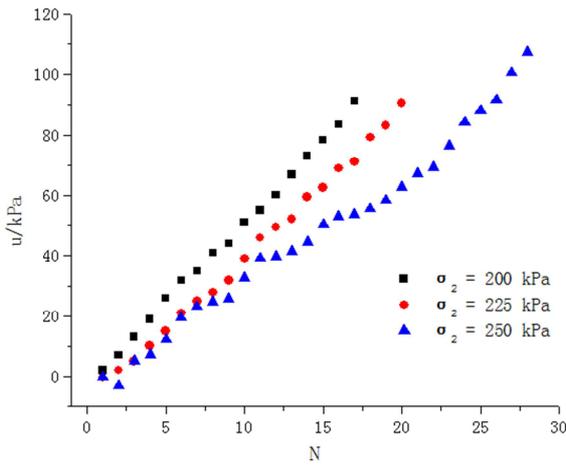
Loading frequency $f = 0.5$ Hz, dynamic stress $\sigma_d = 50$ kPa

Figure 23. Super Pore Water Pressure u against Cyclic Number N .



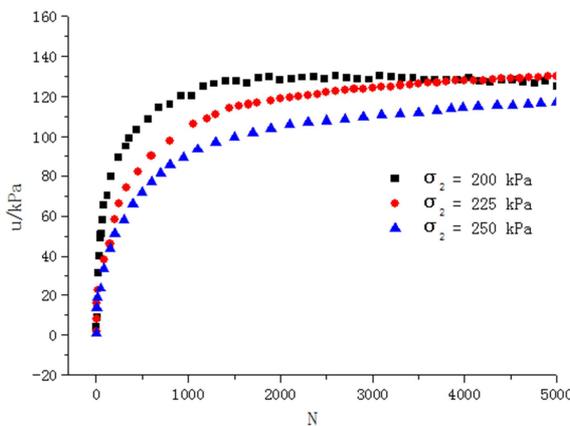
Loading frequency $f = 1$ Hz, dynamic stress $\sigma_d = 50$ kPa

Figure 24. Super Pore Water Pressure u against Cyclic Number N .



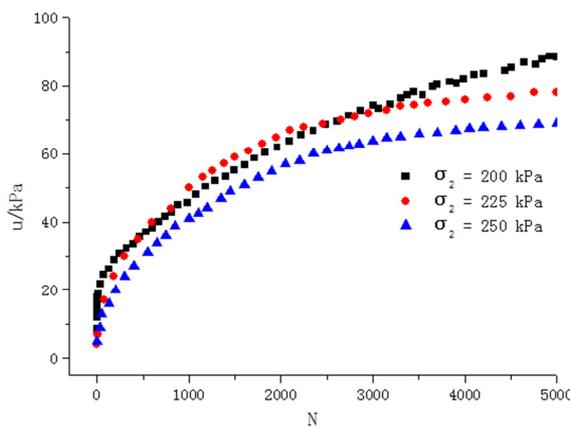
Loading frequency $f = 0.1$ Hz, dynamic stress $\sigma_d = 65$ kPa

Figure 25. Super Pore Water Pressure u against Cyclic Number N .



Loading frequency $f = 0.5$ Hz, dynamic stress $\sigma_d = 65$ kPa

Figure 26. Super Pore Water Pressure u against Cyclic Number N .



Loading frequency $f = 1$ Hz, dynamic stress $\sigma_d = 65$ kPa

Figure 27. Super Pore Water Pressure u against Cyclic Number N .

The curves of the relationship between super pore water pressure u and cyclic number N of different consolidation stress under each loading frequency and 20kPa are shown in Figure 19, 20, 21. Those figures present that anisotropic consolidation lead to the different influence, comparing to loading frequency and cyclic stress, for the construction of

soil. For example, since the reconstruction of soil particle leads to the increasing of the effective stress and reconstruction of drainage passage, in the equal dynamic situation, more energy can be undertaken by the construction of soil, which leads to the less energy of the pore water absorbing and the slower of the pore water pressure increasing speed. Moreover, the higher the frequency is, the more obvious the effect of anisotropy present. The comparison of different consolidation stresses under 0.1Hz are shown in Figure 19, which presents that the final pore water pressure of effective stress 250kPa is as high as the 78% of 200kPa, so that of 1Hz 69%. The dates above shows that the higher the frequency under the same consolidation are, the stronger the anisotropy become.

Moreover, Figure 22, 26 shows that the anisotropy also influence the cyclic numbers of soil developing to failure. For example, the development of super pore water pressure of 65kPa under 0.5Hz is shown in Figure 26. In the isotropic consolidation 200kPa, the pore water pressure increase rapidly when the cyclic numbers N are about 3100, which suggests that the construction of soil change. However, as the intermediate principal stress increase, it can impede, even prevent the soil broken.

According to Figure 1~27, under the traffic load of low frequency, the biggest factor affecting pore water pressure is cyclic stress, followed by loading frequency and consolidation stress. This is because although the consolidation stress can change the arrangement of soil particles, promote pore water drainage and improve soil effective stress, many structural changes are fundamentally impossible due to the low structure of the muck soil compared to clay. While at low frequency 0.1Hz ~ 0.5Hz, the time of pore water absorbing the energy from cyclic loading is similar, which weakens the effect of loading frequency. In contrast, from previous studies, cyclic stress is the key factor of pore water pressure rising, which is due to the pore water pressure absorbing energy. Therefore, the cyclic stress is the most critical factor for the growth of the pore water pressure.

4. A New Pore Pressure Model and Its Parameters

Since the development of pore pressure of muck soil under traffic loading is complicated, it is hard to build a comprehensive pore pressure model. In order to practicality, the convenience of variables should be considered firstly when choosing the model type. Yang Ping [14] suggested that the pore pressure model type of hydraulic is different under low and high frequency. Polynomial is suitable for low frequency while power exponent is suitable for high frequency. Here is the pore pressure model for muck soil in Pear River Delta, which is shown as fellow:

$$u^* = A + B \ln N + C(\ln N)^2 + D(\ln N)^3$$

u^* is the normalized pore pressure. N is the cyclic number. A , B , C and D are the experimental parameters.

Table 3. Parameters of model.

Cyclic Stress/kPa	σ_2 /kPa	f/Hz	A	B	C	D
20	200	0.1	0.01416	-0.07638	0.02934	-0.00164
20	200	0.5	0.00182	-0.01074	0.00152	3.34E-04
20	200	1	0.0022	-0.00741	9.01E-04	2.69E-04
50	200	0.1	0.00786	0.09421	-0.05073	0.00769
50	200	0.5	0.03074	-0.122	0.05066	-0.00347
50	200	1	0.01615	-0.06359	0.02424	-0.00135
65	200	0.1	0.00617	0.07474	-0.04341	0.02525
65	200	0.5	-0.00699	0.04899	-0.00406	0.00131
65	200	1	0.03372	0.054	-0.01595	0.0018
20	225	0.1	0.01709	-0.10444	0.03653	-0.00222
20	225	0.5	0.00559	-0.00889	3.82E-04	3.96E-04
20	225	1	0.00182	-0.00489	2.51E-03	-6.24E-06
50	225	0.1	0.03556	-0.2321	0.07539	-0.00414
50	225	0.5	0.03466	-0.11794	0.04814	-0.00332
50	225	1	0.03135	-0.03177	0.01653	-9.96E-04
65	225	0.1	-0.00493	0.04077	-0.03315	0.02305
65	225	0.5	0.03523	-0.05824	0.03082	-0.0018
65	225	1	0.02541	-0.02273	8.56E-03	-7.23E-05
20	250	0.1	0.01602	-0.06222	0.01953	-8.32E-04
20	250	0.5	0.01055	-0.0107	9.37E-04	3.19E-04
20	250	1	5.47E-03	-1.48E-04	-0.00125	3.37E-04
50	250	0.1	0.0287	-0.17691	0.06316	-0.0036
50	250	0.5	0.05116	-0.05044	0.02104	-0.00118
50	250	1	0.01247	-0.02909	0.01477	-8.43E-04
65	250	0.1	-0.01821	0.08975	-0.06679	0.02575
65	250	0.5	0.03015	-0.03727	0.02153	-0.0011
65	250	1	0.02754	-0.01486	0.00428	2.48E-04

5. Conclusion

The author, firstly, summarize the previous studies on pore water pressure under dynamic stress and take a dynamic test of saturated muck soil, which is carried out by GCTS SPAX-2000 (modified) static and dynamic true triaxial testing system. Here are the conclusions:

(1) In the same cyclic stress and consolidation, the final pore water pressure decreases as the increasing frequency.

(2) In the same cyclic stress and consolidation, the influence of loading frequency on the increasing rate of pore water pressure is periodical. In the 0.1Hz~0.25Hz, the increasing rate of pore water pressure is raised by the frequency increasing. However, in the 0.25Hz~1Hz, the increasing rate of pore water pressure decrease as the frequency increase.

(3) In the same loading frequency and consolidation, the higher cyclic stress is, the more quickly the pore water pressure develop, as well as the accumulative pore water pressure.

(4) In the same cyclic stress and loading frequency, isotropic consolidation can increase the effective stress of soil and slow down the development of pore water pressure, but it is not the key factor.

(5) During the loading frequency of 0.1Hz~1Hz, the key factor of influencing the pore water pressure is cyclic stress and the following is the loading frequency, consolidation is the last one.

(6) Considering cyclic stress, loading frequency and

consolidation, a model of pore water pressure based on an math model is built up:

$$u^* = A + B \ln N + C (\ln N)^2 + D (\ln N)^3$$

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