Study on the application of excess pore water pressure in analyzing the effect of dynamic compaction for the subgrades filled with aeolian sand and gravel soil underwater

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Abstract: This text selects subgrades filled underwater in the section of Taitema lake of an expressway project in Xinjiang. The underwater deep treatment of aeolian sand and gravelly soil subgrades were carried out by dynamic compaction, and excess pore water pressure of that was monitored during compaction. The consolidation effects after dynamic compaction were compared. The results showed that: After dynamic compaction, excess pore water pressure in subgrades of aeolian sand and gravel soil increases as the number of tamping, and dissipates quickly after tamping. The subgrade strength of aeolian sand and gravel soil is improved obviously after dynamic compaction, but the overall reinforcement effect of gravel soil subgrade is better than that of aeolian sand subgrade, so gravel soil should be chosen first when the subgrade is filled underwater.

1. Introduction

There is a lot of aeolian sand and Gobi gravel soil in Xinjiang and other western regions of China. Aeolian sand and Gobi gravel soil can be used as subgrade filling when building roads in these areas. Research[1~2] shows that eolian sand is not a good natural backfill. Gobi gravel soil is a good natural Backfill materials that were widely used in subgrade filling in the western region. However, there are subgrades filled underwater in Taitema Lake of a expressway project in Xinjiang, and there is abundant aeolian sand near the project, but the transportation distance of gravel soil is long to the project, the construction cost is high if gravel soil is used to fill the subgrade. Therefore, it is meaningful to study whether aeolian sand can replace the gravel soil for underwater filling of the subgrade.

At present, scholars[3~4] have conducted a large number of effective studies on the engineering characteristics of aeolian sand and it has been successfully applied to some highways. The research on the treatment method of aeolian sand mainly focuses on the shallow surface treatment of the aeolian sand roadbed by vibration rolling, while the research on the deep or underwater treatment of the aeolian sand filled roadbed is still rare. As for the deep treatment of gravel soil under water, the research[5~6] found that the deep treatment of the gravel soil underwater filling can be carried out by dynamic compaction. At the same time, aeolian sand also has a loose grain structure and has strong water permeability, and it can also be treated by dynamic compaction.
In this text, the test study on the deep treatment of subgrade filled with aeolian sand and Gobi gravel soil by dynamic compaction is carried out, and excess pore water pressure of that was monitored during compaction, the consolidation effects after dynamic compaction were compared by excess pore water pressure.

2. Design of dynamic compaction test

2.1. Test location and subgrade layer distribution
Selected the K328+90~K328+140 of aeolian sand backfill subgrade and K333+640~K333+690 of Gobi gravel soil backfill subgrade in the Taitema Lake to carry out the dynamic compaction test. This test mainly focuses on the study of subgrade treatment underwater by dynamic compaction. The treatment depth below the water surface is about 5m.

2.2. Tamping point plan layout and construction parameters
According to experience, the grid spacing between dynamic compaction points is generally 1.5 to 2.5 times of the tamper diameter, that is, 3.0~5.0m. This test adopts two grid spacing of 3.5m and 4.5m. For the test, each test group is divided into 2 trial areas, and the construction parameters are shown in Table 1.

| Number | Tests                              | Trial areas  | Grid spacing | Energy    | Tamper of point | Energy of ironing |
|--------|------------------------------------|--------------|--------------|-----------|-----------------|------------------|
| 1      | Test group of aeolian sand         | Trial area 1 | 3.5m         | 1500kN.m  | Mass 15 tons,   | 1000kN.m         |
|        |                                    | Trial area 2 | 4.5m         | 2500kN.m  | diameter 2m     |                  |
| 2      | Test group of gravel soil          | Trial area 1 | 3.5m         | 1500kN.m  | Mass 15 tons,   | 1000kN.m         |
|        |                                    | Trial area 2 | 4.5m         | 2500kN.m  | diameter 2m     |                  |

2.2.1. Point tamping
Trial area 1 adopts 1500kN.m of energy and 3.5m of grid spacing. Trial area 2 uses 2500kN.m of energy and 4.5m of grid spacing, all of which are arranged in equilateral triangles. The unit drawing of tamping points layout are shown in Figure 1.

![Figure 1](image1.png)  
Figure 1 Unit drawing of equilateral triangle layout of tamping points in test area (unit: mm)

2.2.2. Ironing tamping
After the points tamping are completed, perform ironing tamping. Energy of ironing tamping is 1000kN.m. The numbers of drop are 2, and the tamping pass is 1. Overlap length is 1/4 times of tamper print.

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2.3. Arrangement and quantity of monitoring and effect testing

2.3.1. Monitoring of excess pore water pressure
Excess pore water pressure generated by dynamic compaction can reflect the impact range of dynamic compaction in the treatment depth and horizontal direction. At the same time, it can monitor the change of excess pore water pressure in the soil after dynamic compaction to understand the dissipation of the excess pore pressure in the reinforced soil. Two sets (4 numbers) of pore water pressure gauges were buried near tamper point A3 of the trial area 1 and tamper point B3 of the trial area 2 of each group of tests. The layouts are shown in Figure 2.

2.3.2. Test of foundation
Heavy dynamic penetration tests were carried out on the foundation after dynamic compaction to study the effect before and after reinforcement. Each test area tests 2 heavy dynamic penetration test points before and after dynamic compaction, of which one is located at the center of the compaction point, another one is located at the midpoint of the line connecting the two compaction points.

3. Analysis of test results

3.1. Excess pore water pressure

3.1.1. The law of excess pore water pressure in the horizontal direction
Select the monitoring results of aeolian sand and gravel soil in tampering points of A3 and B3, respectively, and draw comparison curves of excess pore water pressure with time in depth of 3m of aeolian sand and 2.5m of gravel soil. As shown in Figure 3.
The abscissa "relative time" in the figure refers to the time relative to the first drop. When the excess pore water pressure reaches the peak, the settlement of tamping point meets the standard, and the subsequent curve is its dissipation process.

According to Figure 3, at the same depth under the two energies, the excess pore water pressure of gravel soil at the distance of 4.5m from the center of the tamping point is basically the same as that at the distance of 3.5m, while the excess pore water pressure of aeolian sand at the distance of 4.5m from the center of the tamping point is greater than that at the distance of 3.5m. It indicates that the soil at a distance of 4.5m from the center of the tamping point under the two types of fillers can be effectively reinforced. At the same time, Figure 3 also shows that under the same energy, the excess pore water pressure of the gravel soil backfill at the same distance from the tamping point is greater than that of the aeolian sand, indicating that reinforcement effect of the gravel soil backfill is better than that of aeolian sand backfill in the horizontal direction under the same energy.

It can be seen from the dissipation curve of the excess pore water pressure in Figure 8, that most of the excess pore water pressure of the aeolian sand and gravel soil backfill layer dissipates rapidly after tamping is completed, and then the dissipation becomes slower. After about 3 hours, the degree of dissipation exceeds 80%, so when there are multiple passes in dynamic compaction, both types of backfill can be continuously tamped without waiting time.

3.1.2. The law of excess pore water pressure in the depth direction
Select the monitoring results of aeolian sand and gravel soil, respectively, and draw comparison curves of excess pore water pressure with time. As shown in Figure 4.

Based on Figure 4, it shows that at the same tamping point distance under the two energies, the excess pore water pressure at the depth of 2.5m are basically the same with that of 5m. The soil of two depths has the same reinforcement effect, and the reinforcement effect hardly decreases with the increase of depth. However, the excess pore water pressure at the depth of 3.0m for the aeolian sand backfill is greater than that of 5m. The reinforcement effect of the upper depth soil is better than that of the lower depth soil. The reinforcement effect gradually decreases with the increase of depth. At the same time, the comparison curves also show that under the same energy, the excess pore water pressure of the gravel soil backfill is higher than that of aeolian sand backfill, it indicates that the consolidation effect of the gravel soil backfill in the depth direction is better than that of the aeolian sand backfill under the same energy, especially the lower soil.

3.2. Reinforcement effect test
After dynamic compaction, two groups of heavy dynamic penetration tests were carried out on the aeolian sand and gravel soil (2 tests points in each group: center of tamping point, center of 2 tamping points), as shown in Figure 5.
From the comparison in Figure 5, it can be seen that the blows of heavy dynamic penetration for gravel soil at center of tamping point and center of 2 tamping points are all greater than that of the aeolian sand backfill under the same energy. It shows that the reinforcement effect of gravel soil is better than that of aeolian sand under the same energy.

4. Conclusions
The consolidation effects of aeolian sand and gravelly soil after dynamic compaction were compared by excess pore water pressure. The main test results are summarized as follows.

(1) Most of the excess pore water pressure of the aeolian sand and gravel soil backfill layer dissipates rapidly after tamping is completed, and then the dissipation becomes slower. After about 3 hours, the degree of dissipation exceeds 80%. Both types of backfill can be continuously tamped without waiting time when there are multiple passes in dynamic compaction.

(2) Based on analysis of excess pore water pressure, the dynamic consolidation effect of gravel soil in both horizontal and depth directions is better than that of aeolian sand. The reinforcement effect test results show that the strength of the gravel soil after dynamic compaction is better than that of aeolian sand, and the reinforcement effect is more obvious.

(3) Gravel soil has the same reinforcement effect hardly decreasing with the increase in depth, while the upper aeolian sand has a better reinforcement effect than that of the lower, gradually decreasing with the increase in depth.

(4) Gravel soil should be preferred for underwater filling. However, the quality of aeolian sand filling needs to be strictly controlled in areas where aeolian sand is rich in storage. If the strength of the foundation can be meet the design requirements after dynamic compaction, it can be considered, otherwise it should be cautious.

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