Application of Foamed Soil in Widening Project of Limited Expressway Subgrade

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Abstract: Lightweight foamed soil has the advantages of lightness, adjustable density and strength, low elastic shock absorption, good workability and environmental protection, and its mechanical properties can meet engineering needs, and it can effectively reduce the uneven settlement of the widened roadbed. Combined with the reconstruction and expansion project of an expressway, this article introduces the settlement monitoring and horizontal displacement monitoring of lightweight foamed embankment on-site, which provides a new way for the highway subgrade widening project.

1. Introduction
Due to the lack of transportation capacity, a highway in north China is needed to be expanded. However, in some sections, there is a problem of limited land occupation, which prevents the use of general grading and widening. For this reason, it was decided to widen the expressway with the lightweight foamed soil walls. Regarding the technology related to lightweight foamed soil, research teams around the world have done a lot of research on it, involving various aspects.

Jun, et.al. [1] studied the bubble distribution and mechanical properties of the lightweight foamed soil sample at Kumamoto Airport in Japan. Yoichi and Noguchi [2] analyzed the foam light soil filling technology of an auxiliary road at Tokyo Airport and the perform of it through post-construction settlement observation, which obtained the relationship between the settlement and construction duration, he also verified the advantages of light foam soil filling technology and the good economic benefits. Satoh et.al [3] made a scientific comparison of the Kumamoto port using foam light soil and EPS light soil to fill, and finally concluded that the foamed light soil is more suitable as port filler. At the depth of the 10th meter, the wet density is the same as the 28-day solid density after one year, and the strength is increased by 40%.

Li [4] introduced the production and construction technology of lightweight foamed soil, as well as its self-supporting and light-weight characteristics, focusing on its advantages of no pollution and high economic efficiency. It also has the solution to the problem of jumping at the bridgehead with significant affection. Chen [5] introduced the use of lightweight foamed soil to solve the problem of uneven settlement of roads and bridges and the difficulty of tamping, and summarized the convenience and economy of lightweight foamed soil construction. Xiao [6] introduced the basic properties of lightweight foamed soil materials, and listed the fluidity and bulk density of lightweight foamed soil as the items that must focus on control and inspection in engineering construction.

Lightweight foamed soil has the advantages of lightness, hardenability, adjustable strength and density, almost no pollution. It also can be adapted to various environments. Compared with the
general form of widening of filled soil and widened reinforced earth embankment, the foamed soil embankment is more convenient to construct and needless for ramming. It is a solution for quick construction with less post-construction settlement. However, at present, there are many studies on the physical and mechanical properties of lightweight foamed soil, as well as construction studies on ports, airport runways, and road and bridge transition sections. For lightweight foamed soil, it is used to widen the subgrade of old highways and solve the uneven settlement of new and old subgrade. Researches on areas such as land occupation and limited areas are still insufficient. This article will combine the freeway reconstruction and expansion project, focusing on the use of lightweight foamed soil to provide reference and practical experience for similar projects in the future.

2. Project Overview
This article mainly relies on reconstruction and extension project of a freeway in north China. The road section was converted from the original four-lane to six-lane.

The area has a warm temperate continental monsoon climate, with an average annual temperature of 13.5°C, annual average precipitation of 558.7 mm, rainfall mostly concentrated in July and August, and frozen soil depth of 56 cm. The stratum soil is mainly shallow silt, silty clay, and middle sand and coarse sand in the lower part. There are scattered distributions of soft soil and weak soil in the form of lenses, with a shallow burial depth, distributed on both sides of the old roadside ditch. The engineering geological conditions are better.

However, due to the flat terrain of the area along the line, the villages and towns in this area are relatively dense, making it difficult to acquire land in this section. In order to solve the problem of limited land occupation and uneven settlement of new and old roadbeds, it is proposed to use the foamed light soil wall on roadbed widening. Due to the risk of slippage and overturning of the wall, the monitoring on lateral displacement and settlement of embankment were carried out.

3. Results and analysis

3.1. Settlement monitoring of the widened embankment
There is greater risk of overturning for higher walls. Therefore, in order to maximize the monitoring effect on the safety of the embankment, a section of the highest foamed light soil wall is selected, and it is also the bridge abutment embankment transition section. The schematic diagram of the cross section is shown in Figure 1.

![Figure 1. Layout on settlement monitoring equipment of the embankment.](image)

The filling process and settlement monitoring results of lightweight foamed soil embankment walls are shown in Figure 2 and Figure 3.
As can be seen from Figure 3, the settlement of the foamed light soil embankment is very small during the construction, the settlement peaked at 3.67 cm. Settlement of the embankment during construction gradually increases with time and height, then the rising rate of it slowed down until it stabilizes. It can be seen that smaller settlement appeared at the position near the original embankment. Also, because the mass of the wall is light, the foundation soil rebounded so that the settlement of the basement could be larger than 0, and it disappeared after the next layer is filled.

According to the monitoring data, it can be seen that the settlement of the embankment is small, the settlement has stabilized in the two months after construction, and the settlement barely changes, so the embankment has been stabilized. Therefore, it is a new type of roadbed for the widening measures and it has a significant effect on reducing the uneven settlement of the roadbed.

3.2 Lateral displacement of the widened embankment

The length of the foamed light soil embankment section is about 220 m, which is a short-circuit embankment between the two bridges. Because the embankment wall has a high risk of slippage, so to ensure the stability of the embankment, lateral displacement of the embankment section was observed. There are 12 observation points on the wall. In order to better observe the changes in settlement and discover the potential slippage, two rows of observation points are placed on the wall, the first row is 1 m above the ground, and the distance between each point is 40 m; the second row is 3 m above the ground, and the distance between each point is 40 m. The monitoring results of the horizontal displacement of the foamed light soil embankment wall are shown in Figure 4.
As can be seen from Figure 4, the lightweight foamed soil embankment wall has a horizontal movement of the wall during the construction phase. The maximum horizontal movement of the observation point is 36 mm in 203 days. From the density of the line in the figure, we can see that during the construction stage, the horizontal displacement of each observation point of the embankment wall has been increasing, but the amplitude of its increase has gradually decreased with time, and its growth rate has changed from 9 mm per month to 3 mm per month, indicating that the wall is gradually stabilizing. It can be seen from the lateral displacement of each observation point in the same period that the embankment wall near the bridge abutment has a larger horizontal displacement, and the other positions have a significantly smaller displacement. According to the design, this is related to the highest height of the wall at the abutment. The construction was completed and opened to traffic at the day 252 after construction. It can be seen from the figure that the measured value of day 278 remained stable, indicating that the stability of the embankment wall is good. The above phenomenon shows that the horizontal movement of the foamed light soil embankment wall section is small, and is close to a stable state, which can meet the requirements of subsequent construction and future highway operation.

4. Conclusions

Based on a high-speed reconstruction and expansion project in the north China, this paper studies the application technology of using lightweight foamed soil for roadbed widening, and analyzed the advantages and practicality of lightweight foamed soil, and obtains the following results:

(1) It can be obtained by monitoring the settlement of the foamed light soil embankment wall. The foamed light soil embankment wall can give full play to the lightness of the foamed light soil. The settlement within 3 months after construction is only 3.67 cm, which can effectively solve the problem of uneven settlement of the widened roadbed.

(2) By monitoring the horizontal displacement of the lightweight foamed soil embankment wall, it can be obtained that the lightweight foamed soil embankment wall can maintain a stable combination with the old subgrade, and the maximum horizontal displacement within 5 months after construction is only 36 mm.

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