Application of Improved Silty Fine Sand Filling in Railway Subgrade

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Abstract: In the light of the engineering characteristics of silty fine sand, this paper combines two engineering examples of Inner Mongolia Tongliao-Huolinhe Railway and Inner Mongolia Beijing-Tongliao Railway, respectively, physical and chemical improvements are used to study the effects of improvement measures, construction techniques and other factors on the degree of compaction of railway subgrade. The results show that the compaction of the railway subgrade has been significantly improved after the physical improvement with the addition of Group A soil and the chemical improvement with the addition of cement, which can meet the specification requirements. This shows that the improved scheme in this article is effective, and can provide engineering cases for the construction of related silty fine sand railway subgrade.

1. Introduction

The railway subgrade should ensure the smooth and safe operation of vehicles. In addition, it should ensure that the pavement can withstand the train load. Therefore, the railway subgrade must have sufficient strength, stiffness, permeability resistance and water stability to ensure its overall stability. As group C filler, fine sand needs to be improved before it can be used as railway subgrade filler due to its difficulty in compaction. The corresponding improvement schemes include physical improvement and chemical improvement.

The so-called physical improvement refers to the incorporation of coarse-grained soil such as coarse sand, pebbles and gravels into soil samples, thereby improving the physical and mechanical properties of fillers. The research results of Fan and Wang show that natural fine sand can be used to build high-quality railway subgrade by filling well-graded or cohesive seals (thickness greater than or equal to 0.4 m) on fine sand filler[1]. Through the compaction test of fine sand subgrade filler in Shenyang-Jinbowan Railway, Wang found that the compression modulus of fine sand increases after increasing compaction work and the fine sand becomes denser[2]. The study of Sun showed that the foundation coefficient K30 can be improved to a certain extent by adding gravel sand into the fine sand subgrade filler[3]. Ma found in the physical improvement test of the filler of the two-Iraq railway that when the volume ratio of gravel sand to fine sand reaches 7: 3, and the relative density of the subgrade filler can reach more than 0.81 after six times of vibration rolling, and the foundation coefficient K30 exceeded 100 MPa/m[4]. The
compaction standard of the embankment at the bottom of the subgrade and below can meet the requirements.

The so-called chemical improvement refers to the incorporation of lime, cement, fly ash and other curing agent materials into soil samples to improve the engineering performance of soil and achieve the improvement effect. Jia used 5% cement content modified fine sand as base bed bottom filler to fill the test, the results show that the cumulative settlement deformation of the central surface of the embankment is 150 ~ 191 mm, which meets the specification requirements[5]. Tang studied the cement improvement fine sand of Data-Hejiata Railway, and obtained the best cement content of Data-Hejiata railway subgrade[6]. Ma carried out chemical improvement on the silty sand subgrade of Han-Yi high-speed railway[7]. The test results showed that the maximum dry density of the mixture decreased, and the optimal moisture content increased slightly by adding cement and carrying out compaction test on the improved soil.

Lei and Huang took the subgrade soil of Baotou-Shenyang Railway as the research object, the cement improvement of the fine sand soil sample was carried out to study the engineering characteristics of the improved fine sand under different environments[8]. The samples of different ages were placed in different environments, and the unconfined compressive strength, moisture content and mass change of the samples were detected. Zhang carried out dry-wet cycle test on cement modified fine sand with 46.53% fine particle content to study the influence of different influencing factors on the durability of modified soil[9]. Shen et al. respectively used cement improvement, lime improvement and sand mixing measures to improved filling test of fine sand, and obtained the improvement scheme suitable for the application of Xinertao Railway[10].

In this paper, the physical improvement and chemical improvement schemes are adopted for Tonghuo Railway and Beijing-Tonghua Railway in Inner Mongolia, respectively, and the improvement measures and construction technology are experimentally studied.

2. Physical improvement treatment of fine sand filler in subgrade of Tonghuo Railway in Inner Mongolia

2.1. Engineering situations
Inner Mongolia Tonghuo Railway is 419 kilometers long, from Tongliao to Huolin River in Inner Mongolia. Only a small amount of fine sand with fine particle content less than 5% and good gradation can be used as group B filler, and the rest can only be used as group C filler. The fine sand has a relatively special composition, structure and physical state. If the fine sand is directly used as the railway subgrade filler, the bearing capacity of the subgrade is low, and the overall stability is poor, which does not meet the design requirements of the subgrade bed filler.

2.2. Improvement scheme
There are two soil improvement schemes for Group C: The first scheme is a physical improvement scheme, that is, the A soil is added to the C fill, and the construction method is road-mix; The second is a chemical improvement scheme, that is, the C soil is mixed with cement, it adopts a combination of field mixing and road mixing.

In the first scheme, the soil source of group A is from Longteng quarry in Zarut Banner, the average distance is about 49 km, and the freight is about 65 yuan/m3. In the second scheme, because the construction period belongs to the dry wind season, the average wind speed is 3 ~ 4.4 m/s, which is not conducive to cement mixing, and the water source in this area is extremely scarce. After technical comparison, the physical improvement scheme is decided.

In Code for Design of Railway Earth Structure (TB10001-2016) [11], it is stipulated that the relative density of the bottom of the foundation bed should not be less than 0.75, and the foundation coefficient K30 should be more than 100 MPa/m when sand materials are used for filling. To this end, this paper attempts to select two mixture ratios for the test: one volume ratio is A group of soil: C group of soil = 1: 4. The test results show that the relative density of the improved silty sand subgrade soil is 0.71, and
the foundation coefficient K30 is 90 MPa/m, which does not meet the specification requirements. The two-volume ratio is group A soil: group C soil = 1:3. The experimental results show that the average relative density of subgrade soil is 0.78, and the average value of foundation coefficient K30 is 105 MPa/m, which meets the specification requirements and meets the construction conditions.

Table 1. Experimental data of improved soil.

| Type of blending | Volume Ratio | Relative Density | K30   |
|------------------|--------------|------------------|-------|
| A:C              | 1:4          | 0.71             | 90    |
|                  | 1:3          | 0.78             | 105   |

In the selection of construction scheme, because the physical improvement of fine sand mostly adopts road mixing method, it is prone to uneven mixing of fillers. In order to solve this problem, this paper improves the road mixing construction machinery. Two feeding ports were used to control the mixing ratio by feeding at different speeds, and fully mixed and stirred through the intermediate drum to solve the problem of uneven filler mixing. That is, through mechanical control, reduce the interference and differences of manual operation. In the process of construction, to achieve better compaction effect, measures are taken to seek compaction while spraying water, and the compaction degree is improved by integral displacement vibration static pressure.

Figure 1. Site operation

3. Chemical improvement treatment of fine sand filler in subgrade of Beijing-Tonghuo Railway in Inner Mongolia

3.1. Engineering situations
The electrification transformation project of Inner Mongolia Jingtong Railway is located in the eastern part of Inner Mongolia. The length of the line is 446.2 km. The filler of group C at the bottom of the decontamination line is silty fine sand. The particle size of silty fine sand is single, mostly between 0.075 and 0.3 mm. Poorly graded ultra-fine sand cannot be directly used as a railway subgrade filler, otherwise the bearing capacity and anti-deformation capacity of the subgrade cannot meet the design requirements.

3.2. Improvement scheme
In the construction, the compaction degree of group C subgrade filler is improved by using 20 T vibratory roller to meet the design requirements of railway subgrade. A variety of ways have been adopted, such as static pressure 1 times + weak vibration 2 times (3 times, 4 times) + strong vibration 2 times (3 times, 4 times) + static pressure 1 times rolling, and the compactness cannot meet the design and specification requirements. The chemical improvement scheme was determined after the economic comparison and selection of the two schemes of physical improvement and chemical improvement. In order to improve the compactness of subgrade filler, 3 % Portland cement is added into group C filler, which requires strength grade not less than 42.5, initial setting time not less than 3.0 h, and final setting time not less than 6.0 h. The stability and strength indexes should meet the requirements of Common
Portland Cement (GB175-2020)[12]. The experimental results show that the average relative density of subgrade soil is 0.81, and the average foundation coefficient K30 is 110 MPa/m, which meets the requirements of Code for Design of Railway Earth Structure.

During construction, the thickness of the filler loose paving is controlled at about 50cm, and the construction machinery adopts a vibrating roller, which requires an exciting force of more than 36t. When the solution of static pressure 1 time + vibration 4 times + static pressure 1 time is adopted, the degree of compaction can reach 0.93, and when the solution of static pressure 1 time + vibration 6 times + static pressure 1 time is adopted, the degree of compaction can reach 0.94. All meet the requirements of Code for Design of Railway Earth Structure.

Table 2. Report of the test section for chemical improvement treatment of fine sand filler in subgrade of Beijing-Tonghuo Railway in Inner Mongolia.

| Filler Paving Thickness (cm) | compacting scheme (times) | degree of compaction |
|-----------------------------|--------------------------|---------------------|
|                             | static pressure | pulsation | static pressure |     |
| 50                          | 1              | 4         | 1              | 0.93|

4.Conclusions

In this paper, the improvement scheme of fine sand of subgrade soil powder is discussed. In the Tonghuo railway project of Inner Mongolia, the physical improvement is carried out by adding group A soil into group C soil with different mix proportions. The results show that when the volume ratio of group A soil to group C soil is 1:3, the subgrade filling meets the requirements of Code for design of railway subgrade. In Jing tong railway project, the compaction degree of subgrade filler is improved by adding 3% ordinary Portland cement into group C filler and rolling it, so that the filler meets the requirements of the prescribed standards after improvement. The research results of this paper can provide reference cases for similar projects.

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