# Design of Remediation Plan for High speed Railway Roadbed Settlement Diseases

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**Abstract.** At the same time, with the development of the economy, the problem of settlement of high-speed railway embankments has become increasingly serious. Solving such disease problems is urgent and conducive to promoting social development and economic progress. This article aims to address some of the problems of roadbed settlement encountered in the current development status of high-speed railway subgrades in China. In order to apply theory to practical cases, this article focuses on a certain section of high-speed railways. Based on the characteristics of settlement diseases and common treatment plans for roadbed settlement diseases, targeted methods for treating roadbed settlement diseases are proposed, such as adding fastening pads, grouting, and a combination of the two methods. Choosing appropriate equipment and materials is also crucial in this process. By consulting design specifications and following a series of steps, a targeted solution was designed. The advantage of this article is that it can fully consider all the problems and precautions in the process of rectifying settlement, but there are also some limitations. At present, the remediation and protection of railway embankments are facing enormous challenges due to climate change.

**Keywords:** High-speed railway; Subgrade settlement; Rectification plan; Mechanical lifting; Grouting filling.

## 1. Introduction

With the continuous development of our country's economy, railway infrastructure has been fully constructed, and the existing railway mileage has been continuously increased, thereby facilitating transportation and improving trade exchanges. But precisely because of this, under the influence of vehicle loads and the natural environment, the diseases of railway subgrade are gradually exposed [1].

To meet the basic requirements of safety and comfort for high-speed railways, it is necessary to ensure a certain degree of stability during the operation of the high-speed railway subgrade. However, due to the long-term exposure of the roadbed to high-speed loads and various environmental factors, the risk of safety hazards, equipment damage, and settlement deformation is difficult to avoid, which poses a serious challenge to the safety of high-speed train operations. Especially in situations where trains pass frequently and carry heavy loads, the problem of roadbed settlement becomes increasingly apparent [2]. Therefore, it is very necessary to conduct in-depth research on the relevant remediation plans for high-speed railway subgrade settlement diseases.

At present, according to the relevant literature review, technical personnel have proposed five schemes based on existing conditions: adjusting the line and slope, adjusting the fasteners, reconstructing the overall track bed, adding rail support platforms between sleepers, and grouting lifting [3, 4]. In addition, some scholars have pointed out that the settlement problem of the roadbed can be solved by local replacement and filling reinforcement methods and cement soil compaction pile reinforcement methods.

By reviewing the data on settlement diseases of high-speed railway subgrade at home and abroad, and sorting out the types and proportions of current high-speed railway subgrade diseases. This article aims to analyze the mechanism of roadbed settlement diseases, and based on this, select materials and supporting construction equipment for the treatment of high-speed railway roadbed settlement diseases, in order to summarize the relevant disease treatment process.

In order to put theory into practical application, this article proposes different degrees of roadbed settlement diseases, combined with common roadbed settlement disease treatment plans, and proposes targeted methods for roadbed settlement disease treatment. By studying and analyzing different cases of roadbed settlement, we aim to deepen our understanding and recognition of the remediation plans for high-speed railway roadbed diseases.

## 2. Current status of China's roadbed

According to the survey, the proportion of roadbed defects in China's ballastless track has reached nearly 5% (Fig. 1), among which the main types of defects include poor drainage, damage to the sealing layer, roadbed settlement, frost damage, etc[1,2].The damage to the sealing layer and poor drainage account for about 50% of the roadbed defect mileage, while the damage caused by mud pumping and roadbed settlement accounts for 5.21% and 18.81% of the total roadbed defect mileage, respectively (Fig. 2). Although only 5% of the mileage is affected by roadbed diseases, due to the huge amount of railway mileage in China, the mileage of roadbed diseases is still a terrifying figure. Moreover, as shown in Fig. 2, roadbed settlement disease is one of the main types of diseases.

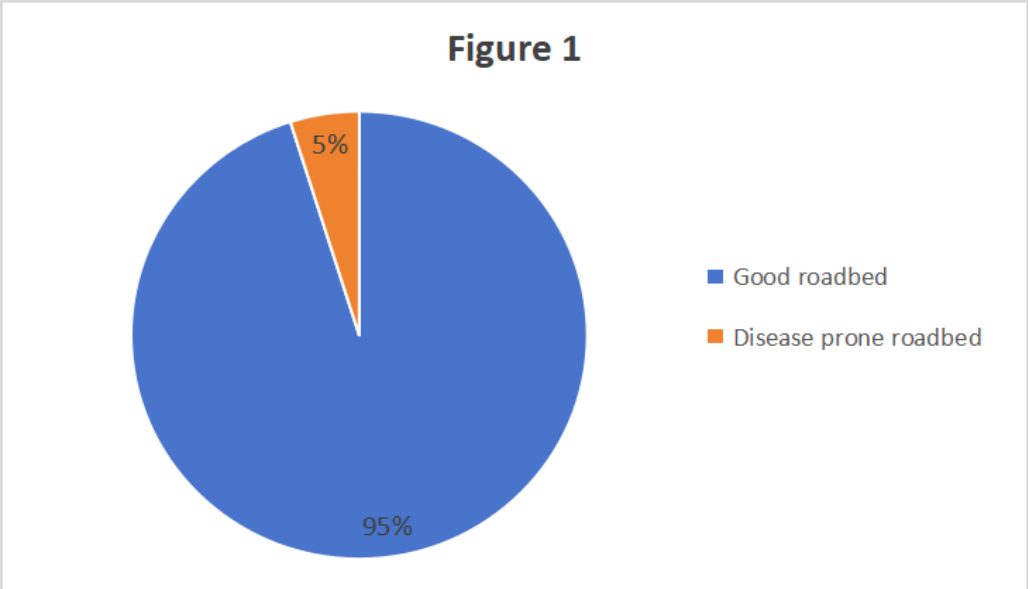


**Fig 1.** Schematic diagram of the proportion of diseases in ballastless track subgrade.

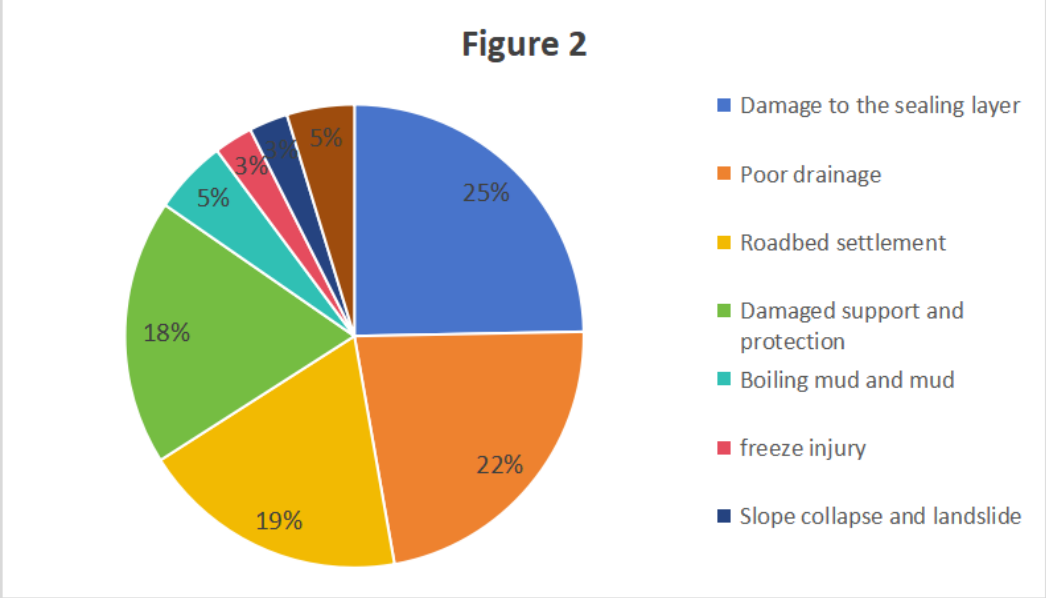


**Fig 2.** Schematic diagram of the distribution of types of diseases in ballastless track subgrade.

Therefore, we should inspect the roadbed and effectively deal with its settlement, which is of great significance for ensuring road traffic safety and extending the service life of railway roadbeds. The issue of roadbed settlement, it should be fully considered in the planning, design, and construction processes, and a comprehensive settlement monitoring system should be established to timely and accurately monitor the roadbed settlement situation, conduct data analysis and processing, and take effective measures to repair it in a timely manner. Only in this way can we effectively maintain smooth traffic and safe driving on the road [5, 6].

## 3. Type of Roadbed Settlement

The high-speed railway subgrade is divided into three different types of settlement according to different degrees, the high-speed railway subgrade is divided into three different types of settlement according to different degrees, namely slight settlement, moderate settlement, and deep settlement.

Slight settlement of the track is a common problem. Minor settlement of railway subgrade refers to the phenomenon of foundation subsidence caused by factors such as pressure and vibration during the use of railway subgrade [7]. Minor settlements will not affect the safety and stability of railway lines, but if the settlement is too large, it will affect the normal operation of railways. The railway management department usually monitors the settlement of the railway subgrade on a regular basis, and once any abnormal situation is found, corresponding repair measures will be taken in a timely manner.

To solve the problem of moderate settlement of railway tracks, multiple factors need to be comprehensively considered, including foundation conditions, track structures, traffic loads, etc. Moderate settlement of railway subgrades refers to the phenomenon of significant subsidence caused by soft foundation, poor drainage, vibration, and other reasons during the use of railway subgrades. Moderate settlement can have an impact on the safety and stability of railway lines, potentially leading to track deformation, unstable train operation, and other issues. The railway management department needs to conduct timely testing and evaluation, take corresponding repair measures to solve the problem of moderate settlement, and ensure the safe operation of the railway line [8]. The repair measures may include reinforcing the roadbed, re-laying tracks, improving drainage, etc.

Solving the serious settlement problem of the track is a complex and urgent task that requires comprehensive consideration of multiple factors and the adoption of effective measures. Severe settlement of railway subgrade refers to the serious sinking phenomenon of railway subgrade during use. This situation is usually caused by factors such as soft foundations, uneven settlement, and soil erosion. Severe settlement can seriously affect the safety and normal operation of railway lines, which may lead to severe deformation of the track, unstable train operation, and even serious accidents such as derailment [9, 10]. The railway management department needs to take immediate emergency measures to repair the severe settlement problem of the railway subgrade. The repair measures may include rebuilding the roadbed, laying new tracks, reinforcing the foundation, and carrying out drainage works. During the repair process, it is necessary to closely monitor and evaluate the condition of the railway subgrade to ensure the effectiveness and durability of the repair work, in order to ensure the safe operation of the railway line. In addition, it is necessary to strengthen the regular inspection and maintenance of railway lines, prevent and promptly deal with the occurrence of railway subgrade settlement problems.

Research on Common Reinforcement Techniques for High Speed Railway Roadbed Settlement Treatment.

1) Adjustment of fasteners and reinforcement of pads: The measure of re adding pads by loosening fasteners at the location of roadbed settlement defects.

2) Grouting reinforcement: By drilling holes in the roadbed and injecting grout material, filling and consolidating the soil, the compressive strength and stability of the soil are improved. Grouting reinforcement can be achieved through methods such as single hole grouting, porous grouting, or segmented grouting.

3) Adjust the combination of fasteners, pads, and grouting reinforcement: By analyzing the settlement of the roadbed, loosen the fasteners and add new pads in areas with low settlement, and inject grout material through drilling in areas with high settlement.

4) Inlay reinforcement: For projects such as roadbed slopes or no end walls, the inlay reinforcement method is used to consolidate the reinforcement material with the soil and improve overall stability.

5) Other reinforcement methods: According to actual needs, structural forms such as retaining walls and retaining walls can also be used for reinforcement to increase the stability of the roadbed.

The common construction machinery used to solve roadbed settlement diseases includes the following.

1) Excavator: Used for excavating roadbed soil, stones, and other materials for leveling and laying the roadbed.

2) Bulldozer: used to level the roadbed soil to meet the design requirements for slope and elevation.

3) Paver: used to evenly lay materials such as gravel and sediment on the roadbed to form a pavement structure.

4) Cement mixer truck: used for mixing materials such as concrete or cement stabilized soil and for the construction of roadbeds and pavements.

5) Forklift: used for transporting and stacking roadbed materials to improve construction efficiency.

6) Railway turnout construction machinery: used for the installation and adjustment of railway turnouts to ensure their normal operation.

7) Measuring instruments: including total stations, level gauges, etc., are used to measure the slope, elevation, and flatness of roadbeds to ensure construction quality.

The above are common equipment used in railway subgrade construction, and different construction projects and project scales may require different combinations of equipment. Reasonable selection and use of construction equipment, strengthened construction management and supervision during railway subgrade construction can ensure construction quality and progress, and ensure the safe and stable operation of railway lines.

## 4. Materials for Disease Remediation

Geosynthetics have been applied in geotechnical engineering for over 50 years. Due to their abundant raw materials, lightweight, high strength, and corrosion resistance, they can compensate for many soil defects, improve soil strength, and increase soil stability. These new materials are placed inside, on the surface, or between layers of soil, playing a role in reinforcement, strengthening, anti-seepage, isolation, drainage, filtration, and protection, and therefore have been widely used.

The main functions of geotechnical fibers include enhancing the mechanical properties of soil or concrete, improving its crack resistance, controlling volume changes, improving durability, and enhancing construction performance. Widely used in fields such as civil engineering, hydraulic engineering, and highway engineering.

The main functions of geogrids include reinforcing soil, dispersing loads, improving drainage performance, preventing soil erosion, enhancing bearing capacity, and improving the environment. It has been widely used in fields such as soil and water conservation, landscaping, and highway construction.

The main functions of geotechnical chambers include soil and water conservation, ecological restoration, prevention of surface erosion, improvement of drainage performance, and enhancement of soil fertility. It has been widely applied in fields such as ecological environment restoration, soil and water conservation engineering, and farmland management.

Design a remediation plan for a roadbed settlement disease that occurred on a high-speed railway.

This article proposes a high-speed railway with a designed speed of 350km/h, using CRTS III slab ballastless track, 60 steel rails, WJ-8 fasteners, and ordinary reinforced concrete track slabs. The surface layer of the subgrade is filled with graded crushed stone (Fig.3).

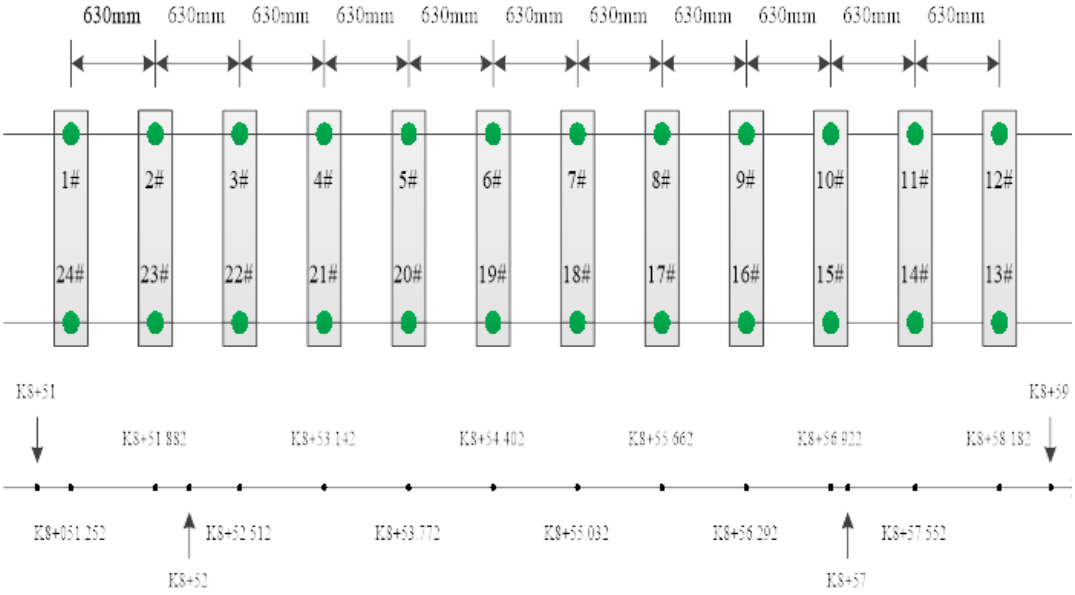


**Fig 3.** Location of the second roadbed settlement (top view).

In the upward direction, the settlement range is K23+128~K23+133, with a maximum settlement of 32 mm. In the downward direction, the settlement range is K23+128~K23+134, with a maximum settlement of 36 mm. The specific settlement data is shown in the Table 1.

**Table 1.** Settlement amount of a certain section of roadbed.

| Upward direction station number | Upward settlement amount/mm | Downward direction station number | Downward settlement amount/mm |
|---|---|---|---|
| K23+128 | 0 | K23+128 | 0 |
| K23+128.17 | 11 | K23+128.17 | 12 |
| K23+128.8 | 25 | K23+128.8 | 23 |
| K23+129.43 | 31 | K23+129.43 | 34 |
| K23+130.06 | 32 | K23+130.06 | 36 |
| K23+130.69 | 29 | K23+130.69 | 28 |
| K23+131.32 | 30 | K23+131.32 | 31 |
| K23+131.95 | 23 | K23+131.95 | 25 |
| K23+132.58 | 13 | K23+132.58 | 18 |
| K23+133 | 0 | K23+133.21 | 9 |
| - | - | K23+134 | 0 |

According to the survey results, the railway subgrade section has a short span but significant settlement, making it unsuitable to use the fastening pad method. To solve the settlement problem, this study chose the grouting jacking method for remediation to improve the stability and bearing capacity of the roadbed.

In order to reduce the uneven settlement of the foundation bed, the reinforcement scheme mainly adopts high-pressure rotary jet grouting piles and flower tube grouting at the upstream direction pile numbers K23+128.17-K23+132.58 and downstream direction pile numbers K23+128.17-K23+133.21 for grouting reinforcement.

When multiple holes are injected into the grouting pipe at the same time, the grouting of adjacent grouting holes will have a height difference effect on the bearing layer of the roadbed. Therefore, first lift the grouting from the point of maximum settlement, K23+129.43-K23+131.32, and K23+128.8-K23+131.95, and then extend it to both sides.

Firstly, the lightweight jacks on both sides and at the center of the support layer are used to lift the track structure. The hydraulic servo system is used to control each lifting device, and the elevation of the track in the range of K23+128.8-K23+131.95 in the upward direction and K23+128.8-

K23+132.58 in the downward direction is adjusted in real-time based on the monitoring data of the line, and grouting is carried out.

Layout of lifting equipment and installation of auxiliary equipment; Drill holes in the concrete on both sides of the track bed at the upstream pile number K23+128.8-K23+131.95 and downstream pile number K23+128.8-K23+132.58, with a spacing of 50cm, and implant 28cm of concrete. Install jacks at the bottom of the angle steel, with a spacing of 1m, and steel plates should be placed on the bottom of the jacks.

According to the exploration results, the drilling machine is used to drill holes at K23+130.06 where the settlement of the upstream pile number is the highest and K23+130.06 where the settlement of the downstream pile number is the highest on the roadbed. The depth usually reaches the design requirements for the stable layer of the stratum to ensure that the grouting material can fully fill the borehole; The drilling depth should be determined according to the depth of roadbed subsidence, generally deep into stable strata to ensure that the grouting material can effectively consolidate the foundation; The spacing between boreholes should be determined according to design requirements, and should be as reasonable as possible while ensuring the reinforcement effect, usually 1.5 to 2 meters.

The design of this scheme mainly adopts deep grouting reinforcement, as deep grouting technology is mainly applied to the reinforcement of road base, subgrade, roadbed and structural foundation; Inject polyurethane slurry (polymer material) into the borehole, and fill the soil layer through the borehole pores to improve the soil's bearing capacity; Inject grout from K23+130.06, where the settlement of the upstream pile number is the highest, and K23+130.06, where the settlement of the downstream pile number is the highest. Then, inject grout in sections and layers towards K23+129.43-K23+128.17, K23+130.69-K23+132.58 in the upstream direction, and K23+129.43-K23+128.17, K23+130.69-K23+133.21 in the downstream direction.

Lifting should be carried out in batches and multiple times. The maximum lifting height value for a single time should consider the tensile strength of the track slab.To avoid cracking of the track slab due to excessive tensile stress, lifting should be carried out in batches, with each grouting height controlled at no more than 20mm. According to the settlement data, the maximum settlement point K23+130.06 needs to be grouted twice (20mm and 10mm respectively) to ensure effective control of settlement. Meanwhile, other areas with significant settlement (such as K23+129.43~K23+128.8) also adopt a similar method for segmented grouting.

## 5. Conclusion

This paper mainly explores the design scheme for repairing high-speed railway subgrade diseases. With the continuous development of the railway industry, relevant departments attach great importance to the comprehensive prevention and treatment of high-speed railway subgrade diseases.

During the writing process of this article, one can become familiar with the basic process of treating roadbed diseases. By consulting design specifications, a series of steps are carried out, such as the main causes of settlement diseases, the selection of remediation materials and machinery, and the process flow of structural lifting grouting. In the process of completing the above content step by step, gaining a certain initial understanding of the design of high-speed railway subgrade disease treatment. Through this design, finding that many professional knowledge only stays at the theoretical stage, and there are still many areas where I do not understand practical applications. In future work, paying attention to both theoretical knowledge and practical skills improvement.

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