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# Reinforcement Technology for Soft Soil Roadbed in the Widened Section of Expressway Expansion

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**Abstract:** This article examines the soft soil roadbed reinforcement technology for widened sections of highways in a specific project. It provides an overview of the project, the principles of soft soil roadbed reinforcement technology for wide sections, and its practical application. The analysis aims to offer guidance on applying soft soil roadbed wide section reinforcement technology and enhancing the overall quality of similar projects.

**Keywords:** Expressway; Expansion project; Widened section; Soft soil roadbed; Reinforcement treatment

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## 1. Introduction

Soft soil roadbed widening is a common procedure in modern expressway expansion projects. For this type of project, the condition of the site should be considered and appropriate reinforcement technology should be employed to ensure that the requirements of the project are met.

## 2. Project overview

The total length of the expressway project studied in this paper was 84.66 km, designed as a two-way four-lane form, and its width was 24.5 m. The highway's pavement was asphalt concrete, with the design speed being 100 km/h. The expressway had been in operation for more than 20 years. The region's socio-economic development resulted in a drastic increase in road transportation needs in that region. Therefore, the engineering unit carried out expansion construction in the form of two-way six lanes based on the actual traffic and transportation conditions and development needs of the area.

## 3. Application principles of soft soil roadbed reinforcement technology for widening sections of expressways

(1) Controlling roadbed filling in the widened sections

During the highway expansion construction, the amount of roadbed filler used should be controlled.

The roadbed filler should be selected based on the traffic load pressure requirements of the expressway design, and appropriate technology and equipment should be used for compaction treatment to control the overall roadbed settlement and ensure the splicing effect of the new and old roadbed [1]. In this project, the roadbed filler was reinforced with ample high-strength materials in accordance with engineering design standards and on-site conditions to prevent settlement deformation between the new and old roadbeds. Large-tonnage impact-type rollers and vibratory rollers were used during the process for thorough compaction.

(2) Improving the bond between the new and old roadbeds

During the widening process of the new and old soft soil roadbed of the expressway, it is essential to strengthen the bond between the new and old roadbeds. This measure is crucial to effectively ensure the reinforcement effect and prevent quality issues resulting from poor splicing between the two sections. By doing so, the structural integrity and stability of the road can be ensured, thereby enhancing the overall quality of the road widening project. In this project, vibration compaction was applied more than four times, followed by impact rolling treatment exceeding ten times to ensure thorough consolidation. This process facilitates the formation of a unified structure between the new and old roadbeds, maximizing stability. Additionally, to seamlessly integrate the two sections, the construction unit excavated multiple steps along the edge of the existing roadbed, each with a width of 1.5 meters and a height of 0.8 meters. These steps were then filled and compacted in layers, allowing for the widening of the roadbed and enhancing overall bonding effectiveness.

(3) Controlling the settlement of old and new roadbeds

In highway expansion projects, it is crucial to manage the difference in settlement between the new and old roadbeds during specific soft foundation reinforcement treatments. While the old roadbed tends to be relatively stable due to prolonged use, the new roadbed typically experiences greater settlement. If not addressed adequately during construction, significant differences in settlement between the two roadbeds can compromise overall quality and stability, impacting the expressway's subsequent usage. To mitigate this issue, measures should be taken to control the difference in settlement between the new and old roadbeds. Typically, this difference should be kept within 3–5 mm. By adhering to these guidelines, the soft soil roadbed at the widened position can achieve optimal reinforcement effects while maintaining stability and quality.

## 4. Analysis of the practical application of soft soil roadbed reinforcement technology in the widened section of the expanded expressway

(1) Preliminary construction preparations

In preparation for the soft soil foundation treatment of the highway reconstruction and expansion splicing construction section, the construction unit undertook several preliminary steps to ensure the effectiveness of reinforcement technology: (i) Conducting a comprehensive survey of the construction site, assessing terrain, soil, groundwater, and climate conditions. Detailed survey results inform subsequent roadbed reinforcement construction planning and technical implementation. (ii) Thoroughly cleaning the construction site by removing all debris and transporting it away promptly. (iii) Selecting a test section within the construction scope based on site conditions and conducting trial width construction according to engineering design standards. This allows for scientific determination and optimization of various construction parameters. (iv) Installing drainage facilities at appropriate locations based on engineering design standards and site conditions to ensure effective roadbed drainage and prevent water accumulation, which could negatively impact roadbed stability. Once these preparatory steps were completed, the construction unit could proceed with splicing the new and old roadbeds according to the engineering design plan. They could also adjust the splicing quality based on actual conditions, further enhancing the splicing effect and ensuring roadbed stability in the widened section.

(2) Compaction design of the widened parts

For expressway expansion projects, achieving the appropriate compaction degree in the joint width of the old and new roadbed is critical for reinforcement treatment. The construction unit must adhere to specific engineering design standards and compaction control specifications, incorporating parameters determined during trial construction to design the compaction degree effectively. Staff should first rigorously test the density of the filler according to engineering design requirements. Compaction can proceed only after confirming that the density meets optimal standards. During compaction, the construction unit should prioritize light compaction initially, followed by heavy compaction using high-power road roller equipment and large cargo for rolling construction. This approach ensures that the widened parts of the new and old roadbeds are sufficiently smooth, preventing unevenness caused by poor compaction design and control. Ultimately, this improves the quality of highway roadbed widening construction and enhances the effectiveness of reinforcement in this section. **Table 1** shows the design standards for the compaction degree of the new and old roadbed widths in this expressway expansion project.

**Table 1.** Design standards for compaction of the new and old roadbed widths

| No. | Project | Depth below the road surface | Compaction design standards |
|---|---|---|---|
| 1 | Roadbed | 0–3 cm | ≥ 96% |
| 2 | Bottom lane bed | 30–80 cm | ≥ 96% |
| 3 | Upper embankment | 80–150 cm | ≥ 94% |
| 4 | Lower embankment | > 150 cm | ≥ 93% |

(3) Soft base treatment and roadbed splicing protection

In highway expansion projects, soft soil treatment and splicing protection are vital tasks in soft soil roadbed reinforcement work [2]. These tasks should be prioritized and reasonable technical measures should be implemented based on the engineering design, operational requirements, and on-site conditions.

There are four main treatment technologies for soft foundation treatment: dynamic compaction, filling and replacement, pre-pressure drainage, and surface layer reinforcement. In this project, the construction unit opted for filling and replacement treatment technology for the widened part of the soft soil roadbed, considering engineering design and site conditions. This approach involves excavating soft soil through machinery and manual methods and replacing it with fillers such as improved soil and gravel [3]. Next, the filling was compacted. This process enhances the bearing capacity and stability of the widened part of the old roadbed, ensuring it meets the subsequent practical application needs of the expressway.

After widening the roadbeds, protective treatments should be carried out to improve their overall stability. Typically, these measures focus on protecting slope stability and preventing erosion [4]. In this project, the construction unit primarily used a combination of engineering protection and vegetation to safeguard the roadbed in the widened area. Considering the local climate, including drought and low temperatures, the construction unit planted vegetation with strong resistance to these conditions on the roadbed slope protection wall. This approach aims to integrate vegetation effectively with the protection wall, improving overall protection quality and ensuring greater stability at the spliced roadbed section [5].

(4) Methods to control differential settlement

Because the bearing capacities of the old and new roadbed materials are significantly different. To ensure stability, the construction unit must control differential settlement in the widened section's soft soil roadbed. This prevents uneven settlement, maintaining the splicing effect between the old and new roadbeds and overall roadbed stability. To control the differential settlement effectively, the construction unit implemented several measures during the project: (i) Continuous cement walls were established on both sides of the old roadbed to prevent disturbance to the base soil during widening construction. (ii) CFG piles were installed on the soft soil foundation at the joint width of the old and new roadbeds, with a concrete strength level of C20 to enhance interlayer bite, strength, and bearing capacity, thus reinforcing the roadbed effectively [6]. (iii) Slopes of each step were cut to a 1:0.8 ratio during the simultaneous widening of the old and new roadbeds to control the excavation slope, preventing instability in the new roadbed slope and reducing excessive differential settlement [7]. (iv) Strict compaction treatment and testing were conducted on the widened part of the roadbed, ensuring adherence to engineering design requirements before proceeding with subsequent construction. These measures enhance the bearing capacity and stability of the widened soft soil roadbed, minimizing the adverse effects of differential settlement on overall reinforcement effectiveness and project quality.

(5) Old roadbed disease treatment design

Treating defects in the old roadbed is crucial for achieving effective reinforcement at the widened part [8]. The construction unit must identify the main issues of the old roadbed through existing data and on-site surveys, then implement appropriate measures to address these issues.

In this project, two main issues affected the old expressway roadbed. Firstly, certain sections of the old roadbed were damaged, leading to uneven settlement in surrounding areas. If left unaddressed, this could compromise the splicing effect between the old and new roadbeds and negatively impact width stability. Secondly, rainwater infiltration in some areas resulted in high soil moisture content, reducing stability and failing to meet the bearing capacity requirements.

Based on the identified issues, the construction unit undertook several measures. This included excavating damaged sections of the old roadbed and replacing them with filler consistent with the new roadbed, followed by compaction. Additionally, in areas with high water content, drainage facilities were installed or compaction drainage methods were employed to enhance stability and bearing capacity. These interventions effectively addressed the old roadbed issues, improving the quality of soft soil foundation reinforcement construction at the joint width of the old and new roadbeds.

(6) Quality inspection of soft soil roadbed reinforcement in the widened section

After completing the soft foundation reinforcement in the widened section, ensuring the effectiveness and stability of the reinforcement required diligent testing of overall processing quality by supervisors. In this project, supervisors primarily focused on testing the joint part of the new and old roadbed in the widened section and the settlement of the edge of the new roadbed. Testing revealed that over time, settlement at the junction of the old and new roadbed and the edge of the new roadbed gradually stabilized, meeting the project's design standards (total settlement $\leq$ 60 mm). These results indicate that the soft soil roadbed reinforcement treatment in the widened section yielded positive outcomes and met the actual engineering design requirements. **Table 2** shows the settlement detection results of the new and old roadbeds and the edge of the old roadbed in this project.

**Table 2.** Settlement detection results of the new and old roadbed width areas and the edge of the old roadbed

| No. | Monitoring time | Monitoring point 1 settlement | | Monitoring point 2 settlement | | Monitoring point 3 settlement | |
|---|---|---|---|---|---|---|---|
| | | Splicing | Edge | Splicing | Edge | Splicing | Edge |
| 1 | 15 d | 6 mm | 8 mm | 8 mm | 8 mm | 6 mm | 8 mm |
| 2 | 25 d | 15 mm | 17 mm | 18 mm | 19 mm | 17 mm | 19 mm |
| 3 | 65 d | 24 mm | 25 mm | 25 mm | 26 mm | 25 mm | 26 mm |
| 4 | 85 d | 33 mm | 34 mm | 33 mm | 34 mm | 34 mm | 34 mm |
| 5 | 95 d | 39 mm | 40 mm | 40 mm | 41 mm | 39 mm | 40 mm |
| 6 | 115 d | 42 mm | 44 mm | 43 mm | 44 mm | 42 mm | 44 mm |
| 7 | 125 d | 43 mm | 45 mm | 43 mm | 45 mm | 43 mm | 45 mm |

## 5. Conclusion

Soft soil foundation reinforcement treatment at the widened part of the new and old roadbed is key in highway expansion projects. Therefore, the construction unit should take reasonable technical measures to carry out reinforcement according to the engineering design standards and actual conditions. This will improve their bearing capacities and stability and provide strong support for the subsequent application and development of expressways.

## Disclosure statement

The authors declare no conflict of interest.

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