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Application Research of K30 Testing Method in Gravel Fill Embankments on Highways

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Abstract: Gravel fill embankments are an integral part of highway construction. However, the compaction density of embankments cannot be accurately assessed through the compaction degree of soil subgrade. Utilizing the K30 testing method to evaluate the compaction quality of gravel fill embankments in highway construction ensures the accuracy and reliability of the testing results. In this study, a specific case of a highway gravel fill embankment is taken as an example to explore the application of the K30 testing method, providing valuable insights for reference.

Keywords: K30 testing method; Highway; Gravel fill embankment; Application

Introduction

In the construction of gravel fill embankments for highways, compaction is an indispensable step that significantly influences the subgrade quality. Since the maximum dry density of the fill material cannot be precisely determined, existing specifications lack quantitative standards for controlling the compaction quality of gravel fill subgrades, leading to diverse on-site operational methods. The K30 testing method, also known as the plate load test, has accumulated certain experience and theoretical foundations when applied to crushed stones, large-sized stones, and other granular fills. Its application in the construction of highway gravel fill embankments holds significant value.

1. K30 Testing Method and Its Principles

The K30 testing method involves experiments using a circular bearing plate with a diameter of 300 mm and a settlement of 125 mm to obtain information about the foundation coefficient. The primary approach is to apply loading through heavy objects such as a car on top of a jack, and during the actual test, manual hydraulic pumps are utilized to control the stress, causing the bearing plate to undergo incremental loading. The loads applied in sequence on the pressure gauge and the corresponding settlement displacements measured by the dial gauge are recorded. The test is initiated when the settlement reaches 1.25 mm or when the load intensity significantly exceeds the actual contact pressure limit on-site. Combining the data obtained for each load or displacement, a graph depicting the relationship between load intensity and settlement is designed. The graph allows for the calculation of load intensity at the baseline settlement value, enabling the calculation of foundation coefficients based on this relationship[1].

$$\mathrm{K30} = \sigma s / Ss \quad (1)$$

In the formula, the settlement corresponding to 1.25 mm in the $\sigma - S$ curve represents the load intensity (MPa) corresponding to the baseline settlement value S_S.

Therefore, the K30 testing method makes judgments about the compaction of the subgrade based on the relationship between settlement and strain after the compaction of the fill material. When the settlement is 1.25 mm under conditions of a higher stress-strain ratio, the K30 value of the foundation coefficient increases, indicating a well-compacted subgrade. Conversely, as the stress-strain ratio decreases, the degree of compaction of the subgrade fill material becomes poorer. This method specifically presents the compaction status of the bottom fill material within the 300mm diameter of the bearing plate. Therefore, when applying this method for testing, it is crucial to ensure the uniformity of the fill material surface[2].

2. Development and Conditions/Requirements of K30 Testing Method

2.1 Development of the K30 Testing Method

Since the 1930s, the compactness indicators proposed by the United States, namely the compaction coefficient K, relative density D, and porosity n, have been considered global standards for subgrade compaction quality. Compactness serves as a standard for subgrade compaction quality due to its advantages of convenient on-site testing. The application of the K30 testing method in China's railway system is well-established, covering various facilities, testing methods, and design standards. As one of the indicators for assessing the compaction quality of embankment fill materials, the subgrade coefficient K30 has been incorporated into the "Quality Inspection and Evaluation Standards for Railway Subgrade Engineering." K30 serves as an indicator for both strength and deformation, providing a clear representation of subgrade stiffness and bearing capacity. China has developed the K30 testing method based on its own experience, recent scientific research achievements, and the specific challenges encountered in practical applications[3].

2.2 Conditions and Requirements for the Application of K30 Testing Method

The application of the K30 testing method is influenced by various factors, such as the characteristics of the fill material, gradation, moisture content, and more. Therefore, the effective use of the K30 testing method requires compliance with the following conditions and requirements:

(1)Particle Gradation of the Testing Object. The K30 testing method imposes requirements on the particle gradation of the testing object when applied in practice. Generally, it is suitable for various soils or soil-aggregate mixtures with particle sizes not exceeding approximately 1/4 of the diameter of the bearing plate. If the particle size of the soil in the embankment is significantly large, and the gradation does not meet the specified requirements, the results obtained from the K30 testing method will likely have certain errors, making it challenging to intuitively reflect the compaction situation of the embankment. Based on past experiences, the K30 testing method is suitable for the testing of cohesive and non-cohesive soils with relatively uniform particle size distribution. Additionally, well-graded crushed stone, provided it is uniformly mixed, can also meet the testing requirements. However, if the particle distribution of the crushed stone is uneven, the application of the K30 testing method may not yield accurate results[4].

(2)Handling Under Special Conditions. For certain conditions such as uniformly graded sand prone to moisture loss, surface hard shells, softening, or soil disturbed due to specific reasons, the K30 testing method is primarily applied beneath the disturbed zone. In the case of homogenous soils with a mixture of coarse and fine particles, tests should be conducted within 4 hours after compaction.

(3)Effective Testing Depth. K30 testing should be confined to an effective depth, typically within the range of 400-500 mm. The results obtained from K30 testing reflect the soil characteristics within approximately 1.5 times the diameter of the loading plate below. To capture the conditions of deeper soil layers, it is necessary to integrate and assess the results with other testing methods.

(4)Surface and Weather Conditions. The testing surface must be smooth and free of irregularities. In cases where necessary, a dry mat with a thickness of approximately 3 mm can be laid. Additionally, the testing surface should be as far away from the vibration source as possible, especially in adverse weather conditions when testing should not be conducted. There are various factors influencing K30 testing, with weather being a significant contributor. For instance, moisture content is a fundamental factor causing deviations in K30 test results. Therefore, the application of the K30 testing method is time-sensitive. It is crucial to control moisture content effectively, initiating operations in areas with favorable moisture conditions. When the soil compacted is in an unsaturated state, moisture content significantly impacts its mechanical properties. This variation in moisture content leads to increased variability in K30 test results[5].

(5)Testing Equipment. The K30 testing method requires specific equipment to ensure accurate and reliable results. Key components include the load plate and loading equipment. The load plate is typically a circular steel plate with a diameter of around 30 cm, and it should be equipped with a leveling bubble for precision. Loading equipment mainly consists of a hydraulic jack and a manual hydraulic pump, connected by hydraulic oil hoses. The length of the hydraulic oil hose should not be less than 2m, with automatic open and pause valve joints on both sides to prevent hydraulic oil leakage. The manual hydraulic pump should be equipped with an adjustable pressure relief valve for efficient loading and unloading of the load plate in a graded manner. If a force gauge is used for direct measurement of the applied load, it is essential to control the accuracy of the force gauge, ensuring it meets a precision level of 1%.

3. Application of K30 Testing Method in Highway Stone Filling Embankment

In a certain expressway where stone filling is predominant over soil filling, the roadbed has been designed with stone filling playing a crucial role. For the quality assessment of the stone filling embankment, the K30 testing method can be applied. The specific steps are outlined below:

3.1 Preparation Phase

The main focus of the testing is on the trial section from k67+350 to k67+450. Ten testing points have been selected for this purpose. The compaction of the stone filling roadbed surface is carried out using an 18-ton vibratory roller. The thickness of the stone filling roadbed surface is approximately 50 cm. Through multiple compaction tests, the load plate is brought into close contact with the ground. For locations with larger particle sizes, a layer of dry sand with a thickness of about 3 mm is laid before initiating the test using the on-site compactor as the reactive equipment. To establish the correlation between the K30 subgrade modulus and settlement differences, settlement plates are placed around each subgrade modulus testing point for effective settlement observation[6].

3.2 On-Site Testing

(1) To ensure the load plate is securely fixed, an initial load of 0.01MPa must be applied, with a time limit of 30 seconds. Once the load plate stabilizes, the load is removed, and proper zeroing of the dial gauge is performed, or the percentage technology is recorded, considering the count as the initial reading for settlement.

(2) Increase the load incrementally by 0.04 MPa. If the settlement in 1 minute is less than 1% of the settlement associated with the current load level, record the slight load or settlement value and proceed to increase the next load level.

(3) If the overall settlement exceeds the standard baseline value, which is 1.25 mm, or if the load strength exceeds the limit of the actual contact force, the test should be stopped.

Given that the particle size of the filling stone in the roadbed is relatively large, the uniformity of compaction surface is poor, and there is a problem of particle displacement during rolling. Therefore, two tests should be conducted at each foundation coefficient test point, and the average value should be determined by integrating the results of both tests. After the completion of the K30 foundation coefficient test, it is necessary to set up settlement plates at appropriate locations and conduct settlement observations. The settlement difference at that location after the last rolling should be calculated.

3.3 Experimental Results Analysis

Table 1 presents the results of the experiments.

Table 1. Compaction Coefficient and Settlement Difference Values

Measurement Points	Rolling 4 times		Rolling 5 times		Rolling 6 times	
	K30	Settlement Difference	K30	Settlement Difference	K30	Settlement Difference
1	0.74	8	1.12	6	1.36	4
2	0.93	7	1.38	4	1.43	2
3	0.87	8	1.27	6	1.37	4
4	0.84	10	1.21	7	1.30	3
5	0.69	11	1.19	5	1.31	4
6	0.92	10	1.38	7	1.46	3

Note: The settlement difference here refers to the difference in settlement between this time and the next. For example, the settlement difference at the location after 5 passes is the difference in settlement between the 6th pass and the 5th pass.

After organizing the above test data, a relationship chart between the subgrade modulus and settlement difference was obtained, as shown in **Figure 1**.

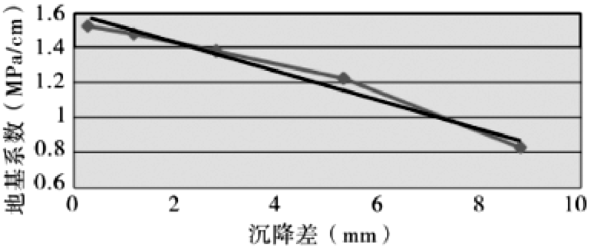

Figure 1. Relationship between Subgrade Modulus and Settlement Difference

(1)From the above figure, it can be observed that the settlement difference is inversely proportional to the subgrade modulus. As the subgrade modulus increases, the settlement difference decreases. Combining with the acceptance criteria for the roadbed section, where a settlement difference of less than 5mm after the final two passes is the control standard, it can be seen that the average settlement difference after six passes of compaction is 3.6mm, meeting the acceptance requirements.

(2)According to the acceptance requirements for roadbed construction quality, the acceptance standard value for subgrade K30 modulus is as follows.

Table 2. Subgrade Modulus Control Index Table for Highway

Location	Fine Sand Soil	Fine Sand	Gravel	Crushed stone	Crushed stone
Base course bottom	0.8	1.1	1.3	1.3	1.6
The embankment beneath the machine bed	0.7	0.9	1.2	1.3	1.4

Combining the on-site test results of the experimental section, it can be understood that there is a certain correlation among the subgrade coefficient, settlement difference, and number of rolling passes. This also indicates the feasibility of applying the K30 testing method to the quality inspection of compacted stone-filled embankments.

4. Conclusion

The application of the K30 testing method in the railway system has a long history. This paper extends its application to the testing of stone-filled road embankments. Based on the comprehensive on-site test results, the following conclusions are drawn:

(1) The application of the K30 testing method in the testing of stone-filled road embankments allows for the determination of the relationship between subgrade coefficient, settlement difference, and the number of rolling passes. This provides a more intuitive representation of the compaction condition of the stone-filled embankment.

(2) Combining relevant standards and test results from the railway department, proposed acceptance standards for the quality of stone-filled road embankments in highway construction.

(3) The K30 testing method demonstrates practicality, a certain correlation with compaction conditions, and universality in control indicators. Drawing on the extensive application experience in the railway system, the application of the K30 testing method in the quality inspection of stone-filled road embankments in highways has significant promotional value.

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