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Application Strategy of CBR Test in Highway Engineering

Yan Liu, Lin Nan, Guangjun Li, Daqing Wu, Shichang Chen, Ke Li*

China Merchants ChongQing Highway Engineering Testing Center Co., LTD., Chongqing 400060, China

***Corresponding author:** Ke Li, 446210395@qq.com

Abstract: California Bearing Ratio (CBR) test is highly professional and requires a high level of skills. In order to improve the accuracy of the test results, the relevant staff will not only need to understand the rules and procedures involved in the test, they would also need to be meticulous in their work to avoid human errors, provide good data support for highway engineering, and improve the overall quality of the project. Therefore, this paper presents an analysis of the application of CBR test in highway engineering, which can provide reference for engineering and promote the development of the highway industry.

Keywords: Highway engineering; CBR test detection technology; Soil quality

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1. Introduction

At present, the highway covers all regions of our country. Due to the vast land area of our country and the complex geological conditions in various regions, the overall quality of highways can directly impact the people's travel safety. Therefore, it is important to improve the overall quality of highways. The California Bearing Ratio (CBR) test is used to carry out detailed inspections on the quality of highway projects to understand the problems and deficiencies in them and implement relevant optimization measures. In this way, the quality of the project can be improved, and this lays a good foundation for the development of the highway industry.

2. Project overview

Taking a highway project as an example, the highway consists of slow lanes and main lines. The total length of the road is 13km, and it is designed according to the two-way four-lane marking. The width of the subgrade and the soil shoulder are 6.5 meters and 0.25 meters, respectively, and the subgrade of some road sections can be up to 8 meters.

3. Overview of CBR test

The CBR test is used to evaluate the bearing capacity of materials, and it is usually applied to road pavement testing. CBR test was first introduced in California, USA. In this test, the load-strength ratio of a standard crushed stone is compared with a sample that is filled to a height of 2.5 mm or 5 mm, usually expressed as percentages [1]. While performing this test, it is necessary to determine the best water content and dry density for specimen preparation. In order to simulate the most unfavorable state of the material, it is necessary to immerse the specimen in water before the test, and this is when a penetration test is carried out, and a load plate is placed on the top surface of the specimen to effectively simulate the additional stress on the soil foundation and the pavement structure. During the penetration test, the larger the bearing capacity of the material, the greater the load pressure that needs to be applied.

4. CBR test

4.1. Principle

CBR test simulates the most unfavorable environment in the actual development and application of the material. Therefore, the material should be immersed in water for 4 days before the test. A penetration test is carried out after the material is immersed in water. In order to simulate the additional stress generated by the subgrade on the soil foundation, a load plate is applied at the top position. As a result, the higher the strength of the material, the higher the value of the CBR in the case of penetrations of 50 mm and 25 mm loads [2].

4.2. Specimen preparation

Proper specimen preparation is crucial in CBR test. First, when sampling, the uniformity and actual position of the specimen will have a certain impact on the test results, so the sampling work must be in strict accordance with relevant standards and specifications. While sampling, the topsoil on the surface should be removed, and the same amount of soil should be taken from the upper, middle and lower layers, or a complete specimen can be taken from a section of equal thickness or width [3]. Second, according to the relevant regulations and standards of our country, the specimens obtained can only be used after passing through a 5 mm sieve. However, this is not possible for samples collected at construction sites, so the samples need to be dried and crushed; if the specimen is clay, in order to crush it, it is necessary to increase time of stuffing to ensure that the soil block can pass through the 5 mm sieve. Third, a 40 mm sieve should be used to remove particles larger than 40 mm, and the proportion of particles larger than 40 mm should be recorded. Fourth, if the same soil has different water content, the strength value obtained will also be different. Therefore, the water content in the material needs to be measured the day before the experiment. The weight of the specimen should be more than 100 grams for fine-grained soil, more than 1000 grams for medium-grained soil, and more than 2000 grams for coarse-grained soil.

4.3. Specimen preparation

The preparation of the specimen mainly includes the following aspects: First, the condition of the particles needs to be fully considered during the selection of the test tube. After the quality is measured by test specimen tube, place it on the bottom plate, and arrange the collar, spacer, and filter paper accordingly. Second, in order to achieve the maximum dry density of the specimen, the specimen can be tamped. The samples are prepared in three ways, and three specimens are prepared in each way. Each specimen needs to be divided into three layers during the tamping process, and each layer is rammed for different numbers of times. The first layer is rammed 30 times, the second layer is rammed 50 times, and the third layer is rammed 98 times [4]. Third, the four-point method is mainly used in the screening process of the specimen. After the screening is completed, the specimen is spread on the metal plate, and the water content is calculated under optimal conditions to ensure that moisture content of the material is within the specified range. Fourth, the soil is stabilized with cement. After the soil is infiltrated, cement can be added into the soil. If fine-grained soil is used, the water content in the fine-grained soil should be reasonably controlled. After the cement is mixed with the soil, a wet cloth can be spread on the surface of the specimen in order to reduce the evaporation of concentrated water. If the whole process takes more than one hour, the specimen should be discarded. Fifth, after leveling the compaction mold, the specimen is poured into it. Then, after leveling the surface, the first layer is compacted. The hammer is dropped vertically, usually from a height of 45 cm. After the compaction of the first layer is completed, the height of this layer must be checked, so that the remaining two layers can be adjusted in time. After compaction is completed, the surface needs to be roughened. This process is then repeated for the remaining two layers. Sixth, the collar is removed, the soil on the surface of the compaction mold is smoothened, the pads are taken out, and the total weight of the test tube containing the specimen is weighed. Other types of specimens are also prepared using the aforementioned procedures, with different times of ramming.

4.4. Soaking in water to measure expansion

(i) If plain soil is used as the specimen, the filter paper on the top surface should be replaced after the preparation is completed. Perforated plates should be used to ensure that the pressure on the structural layer of the specimen is consistent with the pressure on the top surface of the specimen. (ii) If the perforated plate and the test tube are placed in the water tank, the mold is tightened, the dial indicator is properly placed, and the readings in the dial indicator are read at the same time [5]. (iii) When filling up the water tank, it is important to make sure that water can enter the bottom and top parts of the specimen. (iv) After the immersion work is finished, read the reading of the dial indicator again, and calculate the expansion at the same time [6]. (v) Take the specimen out of the water tank, wipe the surface water, and remove the bottom plate, filter paper and porous plate after standing for 15 minutes, then weigh the mass of the specimen, and calculate the humidity change and density change of the specimen [7].

4.5. Test and detection instruments

The instruments used in CBR test mainly include penetration rods, test devices, bearing plates, loading devices, and penetration measuring devices. Among them, the loading device mainly includes a car with aggregates. The weight of the rear axle of the car must exceed 60kN, and the beam must be properly set. The test device mainly includes a pressure gauge and a jack. The capacity of the pressure gauge needs to be greater than the strength of the soil foundation, and the measurement accuracy needs to exceed 1% of the total range. The penetration rod is a metal cylinder, usually about 200 mm long, with a diameter of about 50 mm. There are 4 load plates, each of which has the same weight and a diameter of about 150 mm. There are two penetration measuring devices, which are fixed on the penetration rod in a symmetrical way. In addition, instruments such as rulers and balances are also used in CBR test.

5. Results of CBR test

5.1. The effect of immersion time

After compaction was carried out 70 times, the test soil blocks mixed with lime were immersed in water for one day, two days, three days, and four days, respectively before the CBR test was carried out. The results are shown in **Table 1**.

Table 1. CBR value (%) under different immersion time and ash content

Ash content (%) / Soaking time (d)	0	1%	2%	3%	4%
0	48.7	43.6	43.1	43.4	38.5
1 d	25.6	332.7	36.4	33.2	27.4
2 d	21.6	28.8	37.6	33.4	25.3
3 d	21.5	33.8	36.4	42.5	33.6
4 d	20.6	36.8	39.7	48.5	37.1

According to **Table 1**, the soil test block was less stable when no lime is added, and the longer the test soil block was immersed in water, the smaller the CBR value. After the soil was soaked in water for one hour, the decline of CBR value gradually decreased. However, as the soaking time gradually increased, the CBR value also continued to increase. The main reason for this phenomenon is the bonding reaction between soil and lime.

5.2. Effect of ash content on degree of compaction

In order to strengthen and understand the impact of ash content on highway engineering, the degree of compaction can be tested according to the requirements of the CBR test. The specific test results are shown in **Table 2**.

Table 2. Test of influence of ash content on compaction degree (unit: g/cm^3)

Ash content (%) / Compaction (%)	0	1	2	3	4
30 times	90.0	88.2	86.3	85.9	84.7
50 times	94.0	92.4	92.3	91.4	90.5
70 times	98.0	96.7	94.5	94.3	93.5
98 times	99.0	96.9	95.3	94.7	94.1

As shown in **Table 2**, in the case of the same number of compaction, the compaction degree of the test soil block will gradually decrease when the amount of lime added increases. This is because the cohesion of the soil is reduced after the lime is added, and the plasticity of lime soil also reduces [8]. When soil block reacts with the water and lime, the friction between the soil block particles increases, which seriously affects the compaction effect. As the number of compactions increases, the compaction strength of the loess test block is also increases, thereby reducing the compressible space.

5.3. Effect of ash content on CBR

The CBR value of the soil test blocks that were immersed in water for 4 days with different ash content were tested respectively. The specific test results are shown in **Table 3**.

Table 3. Results of the effect of ash content on CBR

Ash content (%) / Compaction (%)	0	1	2	3	4
30 times	5.8	18.5	19.4	22.7	20.6
50 times	8.7	32.6	30.9	36.9	25.7
70 times	24.4	38.4	40.5	47.2	31.0
98 times	22.7	36.7	28.6	29.6	21.8

According to **Table 3**, the increase of ash content resulted in an increase the CBR value. The CBR value was the largest when the ash content was 3%, the CBR value decreased as the ash content increased. This is because the ash content itself has a certain expansion rate and plasticity, so it has a certain stabilizing effect when it is integrated into the soil [9]. However, increasing the amount of lime mixed will reduce the

2. Overview of CBR test

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6. Influencing factors

6.1. Effect of soil quality on CBR

Regolith is the main component of mountain soil. All kinds of crushed stones are aggregated into regolith, so there is no strong cohesive force, and shear strength can only be borne by the internal friction, which mainly includes rolling, sliding, and other resistances. These properties are not directly related to water content, but to factors such as the shape, size, and strength of soil particles. Therefore, the shear strength of mountain soil is mainly determined by the roughness and size of the soil, and will not be affected by water content [10]. The viscosity of the silt is between the hillside soil and the topsoil. Therefore, in general, the greater the viscosity of the soil, the smaller the CBR value, and there is an inverse relationship between the CBR value and the soil viscosity (**Table 4**).

Table 4. Test results of the influence of soil quality on CBR

Soil	Maximum particle size/mm	Liquid limit W_1 (%)	Plastic limit W_p (%)	Best moisture content (%)	Maximum dry density ($g \cdot cm^{-3}$)	Expansion (%)	CBR value (%)
Topsoil	< 4	47.8	22.3	17.3	1.86	25.4	5.6
Silt	7	28.4	19.7	12.8	1.97	1.7	42.9
Mountain soil	12	30.4	18.4	7.5	2.36	0.28	53.5

6.2. Effect of particle size on CBR

See **Table 5** for the changes in CBR values of silt, topsoil, and mountain bark soil with different particle sizes.

Table 5. Changes in CBR values of silt, topsoil, and mountain bark soil

Soil	Maximum particle size/mm	CBR value (%)
Topsoil	4	4.0
	7	4.6
Silt	6	36.8
	8	45.7
Mountain soil	8	46.9
	12	52.7

According to **Table 5**, the CBR value increased as the particle size increased. The maximum particle size of different soils were different. If the particle size is large, soaking in water will not cause much effect or result in much changes in the particle size.

7. Conclusion

In short, the CBR test is a relatively complicated task, involving many procedures. If there is a problem in a certain step of the test, the overall results and accuracy of the experiment will be significantly affected. Therefore, in order to avoid these problems, the relevant staff and testing personnel need to strengthen their understanding of the procedure and the technical points, so as to ensure the accuracy of the results, and provide effective data support for highway construction.

Disclosure statement

The author declares no conflict of interest.

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