Study on Unconfined Compressive Strength of High Volume Cement Stabilized Macadam

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Abstract: This paper mainly studies the effects of different cement content (5%, 7%, 9%, 11%, 13%, 15%) on the unconfined compressive strength of cement stabilized macadam base materials. The effects of different cement content on the compressive properties of the mixture were compared by unconfined compressive strength test analysis. The results show that the influence of cement content on the early strength of the road base layer is greater than the impact on the later strength. When the age is 1 day, the cement content increases from 9% to 11%, and the unconfined compressive strength increase rate of the test piece is the largest (35.93%).

1. Introduction
With the strengthening of the country's economic strength, China's transportation industry has achieved a leap-forward development. As of the end of 2017, the total length of roads nationwide reached 4,773,500 kilometers, an increase of 78,200 kilometers over the previous year. The cement stabilized macadam base is a common type of road base, which mainly bears the weight of the road surface layer and the traffic load transmitted from the surface layer. It can well transfer the load of the surface layer to the roadbed. Many scholars at home and abroad have also conducted in-depth analysis and research on cement stabilized macadam.

By studying the influence of different factors on the strength of cement stabilized macadam, Li Mingjie found that when the cement content was less than 5%, the effect of increasing the cement content on the ultimate strength of cement stabilized macadam was significant; and the gradation type was stable to cement. The strength of the gravel material is more significant, and the skeleton compact type is about 19% higher than the early strength of the suspended dense cement stabilized macadam, and the late strength is about 10%[2]. Sun Zhaohui, Wang Tiebin and others have studied the influence of different factors on the strength of cement stabilized macadam. It is found that when the cement content is between 4.5% and 4.8%, the grading type has less influence on the compressive strength of the 7-day test piece; the strength of the specimen after 28 days decreased as the content of the needle-like sheet increased, but the extent of the decrease is gradually reduced[3]. However, along with the improvement of the national economy and the people's living standards, the number of cars, the variety of cars, and the increasing load of cars have caused many roads to reach their years of use and require multiple reinforcements, which leads to an increase in maintenance costs later.

In this paper, the influence of high-content cement stabilized macadam base layer compressive strength was compared with that of normal cement. The difference between the two was obtained, which provided a theoretical basis for road construction. The high-content cement stabilized macadam...
base was tested with reference to the mix design, mixing and construction methods of the cement stabilized macadam base.

2. Test

2.1. Test raw materials
(1) The cement adopts 32.5 grade composite Portland cement, which meets the relevant requirements of “Technical Specifications for Highway Pavement Base Construction” (JTG/T F20-2015) [5]. Cement Test Parameters is shown in the Tab.1.

| Project               | Initial setting time | Final setting time | 3d  | 28d | 3d  | 28d |
|-----------------------|----------------------|--------------------|-----|-----|-----|-----|
| Skills requirement    | ≥180                 | ≥360 and ≤600      | ≥16 | ≥32.5 | ≥3.5 | ≥5.5 |
| Experimental result   | 230                  | 430                | 18.1| 41.5 | 4.1  | 8.5  |

(2) The aggregates were taken from limestone produced by Daqingshan Stone Material Factory in Hohhot, Inner Mongolia Autonomous Region, meeting the requirements of the regulations [5]. It was divided into three files, which were 0-5mm, 5-10mm, 10-30mm. The material synthesis curve is shown in the figure 1.

2.2. Test methods
This section mainly studies the strength of cement stabilized macadam materials with different cement content (5%, 7%, 9%, 11%, 13%, 15%) and different ages (3d, 7d, 28d, 90d, 180d). Influence the law. According to the relevant provisions of the "Testing Regulations for Stabilizing Materials for Inorganic Bonds in Highway Engineering" (JTG E51-2009) [6], the unconfined compressive strength test specimens are cylindrical specimens of φ15cm×h15cm, and the specimens are formed by static pressure method, and the compaction degree is 98%.

![Fig.1 Aggregate gradation curve](image)

3. Test results analysis

3.1. Unconfined compressive strength analysis
Fig. 2 Unconfined compressive strength changes

It can be seen from Fig. 2 that the unconfined compressive strength of the test piece is enhanced throughout the observation period. When the curing age is 28 days, the strength of the test piece accounts for 70%-82% of the entire observation period. When the age is 90 days, the age of the test piece reaches about 90% of the entire observation period. On the 180th day, the strength of the test piece increased by only 23%-48% compared with 28 days, indicating that the cement stabilized macadam material increased rapidly in the early stage, especially within one month of molding, but the strength of the test piece increased slowly during the post-health period. At the initial stage of the test piece, the age of the test was 3 days, and the strength of the test piece increased by 25.74%, 23.93%, 23.10%, 24.48%, and 15.73%, respectively, in the case of a 2% increase in cement content (5%-15%). And the strength of the test pieces increased by 25.19%, 22.55%, 12.36%, 12.76%, and 9.21%, respectively, under the same conditions of 180 days. It can be seen that when the age of the specimen is 3 days, the increase rate of the strength is higher than that of the 180 day. When the cement content is more than 9%, the phenomenon is more obvious. At the same time, it can be found that when the cement content reaches 15%, the strength increase rate of the specimens decreases in 3 days and 180 days, but the overall strength increases again. It shows that it is not economical and feasible to increase the strength blindly by increasing the cement content, because the increase rate of the early strength and the late strength of the test piece will be reduced when the cement content is more than 13%. At this time, increasing the strength by increasing the amount of cement will only lead to an increase in cost and an increase in strength but not obvious.

Using Matlab’s powerful analytical ability, the curve is fitted and the confidence interval of the curve is determined. And the fitting curves are shown in Figure 3.
In the abscissa of the six figures, it can be found that the age of the test pieces are all 1 day (the system defaults, you can change any time). Corresponding to the different cement content (5%, 7%, 9%, 11%, 13%, 15%), the compressive strengths of the test pieces are 4.04 MPa, 4.89 MPa, 6.13 MPa, 8.33 MPa, 10.23 MPa, and 12.83 MPa, respectively. It indicates that the compressive strength of the specimen increased by 21.06%, 25.31%, 35.93%, 22.68% and 22.47% for each 2% increase in cement content when the test period was 1 day. When the age of the specimen is 180 days, the compressive strength of the specimen is 13.09 MPa, 16.08 MPa, 20.08 MPa, 22.83 MPa, 25.28 MPa, 28.09 MPa, respectively. For each increase 2% in cement, the compressive strength is increased by 22.76 and 24.94, and by 23.68 and by 10.71 and 11.12, respectively. It can be found that when the test piece age is 1 day, the cement content increases from 9% to 11%, the strength increase rate of the test piece is the largest, indicating that the road base layer strength is the fastest. When the cement is increased by 2%, the average increase rate of the specimens with a curing age of 1 day is higher than that of the specimens with a 180-day age, indicating the degree of influence of the cement content on the cement stabilized macadam. It is greater than the degree of influence in the later period. It means that the early strength of road base can be increased obviously by increasing cement content, at the same time the later strength of road can not be attenuated.

3.2. Strength prediction and verification
The compressive strength of the cement stabilized macadam base is the result of the joint action of the age and cement. In order to reflect the influence of the age and cement on the strength simultaneously, the prediction of the non-lateral compressive strength is used to analyze the influence of the two on the compressive strength together[7], and the empirical formula 1 is summarized.

\[ q_{ut} = (-0.036\alpha_c^2 + 1.005\alpha_c - 0.126) \times \log t + 0.086\alpha_c^2 - 0.869\alpha_c + 6.453 \] (1)

Where, \( q_{ut} \) is prediction of unconfined compressive strength (MPa); \( \alpha_c \) is cement content (%); \( t \) is test piece age (d).
In order to more intuitively reflect the effect of the ageing and cement content on the unconfined compressive strength, a three-dimensional surface of the compressive strength is drawn, as shown in Figure 4.

![Three-dimensional surface compressive strength curve](image)

Fig.4 Three-dimensional surface compressive strength curve

In order to respond more intuitively to the equation, the measured value with the predicted value is compared and the 45° contour is plotted as shown in Figure 5. In the comparison results of 30 sets of data, the predicted value of the graph is distributed near the 45° contour, and the relative error is only 4.07%, and the fitting effect is better. It has high repeatability and fitness, which is beneficial to predict the strength of cement-filled gravel materials with different cement content at different ages, and provides reference for the strength of the road.

![Compressive strength model 45° contours](image)

Fig.5 Compressive strength model 45° contours

4. Conclusion

1) Under the premise of the same age, the strength of the test piece is positively correlated with the cement content. When the cement content is 15% at the age of 3d, the increase rate of the test piece strength is reduced, but the strength is still increased.

2) The strength of the test piece in the early stage is more affected by the cement content than the cement content in the later stage. When the cement content increases from 9% to 11% in the first day, the strength increase rate of the test piece is up to 35.93%.

3) An empirical formula of specimen strength and age and cement content was summarized. Through this formula, the strength of any cement and the strength of the specimen at any age can be determined. It proved that this formula could be applied to the raw materials and mix ratios of this experiment.
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