# Test research on influence of admixture agent on engineering characteristics of red sandstone roadbed filling in Dongchang Expressway

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**Abstract:** By taking the red sandstone along the Jiangxi Dongchang expressway as the research object, this article takes lime and cement as the admixture agent, and conducts a series of laboratory test investigations on plain soil and improved soil, to research on the influence of the addition proportion on the physical and mechanical properties of red sandstone. According to test results: compared with plain soil, the red sandstones with admixture agents of lime and cement have reduced liquid limit and plastic limit, with reduced plastic index. With the increase of the proportion of lime, the optimal moisture content of the lime-improved soil gradually increases, and the maximum dry density gradually decreases. With the increase of the proportion of cement, the maximum dry density of the cement-improved soil increases, and the optimal moisture content decreases. The CBR improvement effect of cement-improved soil is better than that of the lime-improved soil. The optimal addition proportion of CBR of both the lime-improved soil and the cement-improved soil is 7%. Compared with plain red sandstone, the improvement on compaction functions plays a more significant role on the improvement of the CBR of the improved soil.

## 1 Introduction

Due to the characteristic of water disintegration of red sandstone, the engineering property after disintegration is very poor[1]. Therefore, improper handling of engineering with red sandstone as the roadbed filling will lead to harmful damages such as road surface collapse, cracking and side slope slump; therefore, it is needed to conduct processing to red sandstone before applying it to engineering. By taking the Nanjing-Huaian highway as the engineering background, Zhang Songnan[2] conducts laboratory test research on the expansive soil along with the highway with lime; Yang Jun et al. [3] conduct test research on the strength characteristic of high liquid limit clay after improvement with weathering sand; by utilizing self-made admixture agent composed by curing agent A and common Portland cement, Cheng Yin et al. [4] conduct improvement on the blown filled muck TT of Tianjin Binhai New Area; according to the result, the strength is increased by 2.4 times than that of cement, when the curing agent A is added with the proportion of 10%. By researching on the ion species existing in hydrolysate, Liu Xiaoming et al. [5] conduct research on the measures to restrain the disintegration of the first type of the red sandstone. According to the result, Ca2+ salt can play a preferable role in restraining the disintegration of the red sandstone in a preferable way; certain test is conducted on the resistance to disintegration, and it is worked out that the addition proportion of 7% of lime is the optimal engineering measure for restraining the disintegration of the red sandstone. Liu Daobin et al. [6] conduct improved curing research on the red sandstone near to Dawu-Suizhou highway by adopting lime, cement, coal ash and their combined matching, and mainly conduct test research on the unconfined compressive strength; according to the result, the self-made liquid curing agent has preferable effect. Wang Zhimeng[7] conducts research on the adaptation of the red bed mudstone and the improved soil in high speed railway bed, and they only conduct CBR test on the lime-improved soil with single proportion, and no optimal added quantity can be obtained.

According to document retrievals, current researches are conducted mainly aiming at expansive soil, high liquid limit clay and mucky soil, and little research on red sandstone improved soil has been conducted, especially on intense weathering red sandstone. At the same time, existing researches on red sandstone improved soil are conducted aiming at the improved soil of single proportion, so the optimal added quantity cannot be obtained. Besides, red sandstone has certain regionality; therefore, it is necessary to research the working properties of different addition proportions by selecting the red sandstone with certain representatives. By taking the intense weathering red sandstone adjacent to Dongxiang-Changfu highway in Jiangxi Province as the research object, to conduct a series of CBR tests on red sandstone after improvement with lime and cement, to research on the working performance of red sandstone under different addition proportions, to work out the optimal addition proportion; besides, it analyzes the influence of the admixture agent on the physical characteristic of red sandstone as well as the CBR influencing factors on improved soil, providing certain reference functions to the construction of the engineering.

## 2 Improved soil test scheme design

### *2.1 Physical Property of Plain Soil and Improved Soil*

The oil used for this test is taken from the Dongxiang-Changfu highway in Jiangxi Province with the depth of 3m away from the earth’s surface. Crush down the soil with wood grinding and griddle with 20mm sifter, and then mix by adding in lime and cement. The slaked lime is used in this test, with addition proportions of 5%, 7% and 9%, respectively; the Little Nanhai brand 42.5 cement is adopted in this test, with the addition proportions of 3%, 5% and 7%. The admixture agent proportion used in this test is the proportion between the mass of the admixture agent and the mass of the dry soil. Mix the lime and the soil before the test, and spray water to the optimal moisture content, and then enclose material for 24h; the cement is added after the 24h of enclosing material of plain soil after spraying water, which is conducted before the test. According to “Test Method of Soil for Highway Engineering” (E40-2007) [8] and “Test Method of Stabile Materials of Inorganic Binder of Highway Engineering” [9], this test conducts a series of laboratory tests to plain soil and improve soil, to measure the physical property, as shown in Table 1.

**TABLE 1.** Physical Index of Plain Soil and Improved Soil

| Type of the admixture agent | Addition proportion (%) | Liquid limit (%) | Plastic limit (%) | Plastic index IP |
|---|---|---|---|---|
| Plain soil | 0 | 42.96 | 24.617 | 18.343 |
| Lime | 5 | 40.337 | 25.973 | 14.364 |
| | 7 | 39.941 | 27.915 | 12.026 |
| | 9 | 39.104 | 27.583 | 11.521 |
| Cement | 3 | 42.239 | 25.302 | 16.937 |
| | 5 | 41.549 | 25.095 | 16.454 |
| | 7 | 41.835 | 25.996 | 15.839 |

*2.2 Compaction Test Scheme Design*

According to the "Test Method of Soil for Highway Engineering" (E40-2007) [8], this test method conducts compaction test on plain soil and improved soil with cement and lime by adopting the heavy-II compaction test, with the weight of the compaction hammer of 4.5kg, and the drop height of 45cm, and the test tube of 2177cm3; the compaction is conducted in 3 layers, with 98 times for each layer. Crush down the air dried soil with wood grinding, and griddle with 20mm sifter. As for the lime-improved soil, weigh the air dried soil after griddling of 5kg, and sufficiently mix with lime, and then add in water to set moisture content, and then enclose material for 24h, with the lime addition proportions of 5%, 7% and 9%, respectively. As for the cement-improved soil, weigh the air dried soil after griddling, and spray water to the set moisture content, and then enclose material for 24h, and sufficiently mix the soil and the cement as per preset addition proportion before the compaction test, and compete the compaction test within 1 hour. The cement addition proportions are 3%, 5% and7%, respectively. The compaction result is as shown in Table 2.

**TABLE 2.** Result of Plain Soil and Improved Soil Compaction Test

| Admixture agent | Addition proportion (%) | Optimal moisture content (%) | Maximum dry density (g/cm3) |
|---|---|---|---|
| Plain soil | 0 | 15 | 1.803 |
| Cement | 3 | 17.682 | 1.747 |
| | 5 | 17.613 | 1.781 |
| | 7 | 15.771 | 1.792 |
| Lime | 5 | 14.94 | 1.751 |
| | 7 | 16.852 | 1.721 |
| | 9 | 17.96 | 1.701 |

*2.3 CBR Test Scheme Design*

Determine the optimal moisture content and the maximum dry density of the plain soil and the improved soil as per the compaction test. Please refer to Table 2 for the optimal moisture content and the maximum dry density of plain soil, the cement-improved soil and the lime-improved soil. As for plain soil and lime-improved soil, spray water and mix plain soil and the improved soil with lime according to different addition proportions, and then enclose materials in a sealing way for 24h for standby application, and prepare 3 test specimens with the compaction degree of 93% and the compaction degree of 95%, respectively. As for the cement-improved soil, mix the soil as per the optimal moisture content determined by the compaction test, and then enclose materials in a sealing way for 24h. And then, before the preparation of specimens, sufficiently mix the soil after enclosing and the cement of different addition proportions, and finish the preparation of specimens within one hour. And then maintain for 7d and soak for 4d; during the soaking period, the height of the water shall be at least 2.5cm away from the top of the specimens. Please refer to Test Method[8,9] for the specific operation procedures. The CBR test result of plain soil and improved soil are as shown in Table 3.

**TABLE 3.** CBR Test Result of Plain Soil and Improved Soil

| Addition proportion / Compaction degree | Plain soil | Lime | | | Cement | | |
|---|---|---|---|---|---|---|---|
| | 0% | 5% | 7% | 9% | 3% | 5% | 7% |
| 93% | 4.34 | 57.063 | 73.583 | 69.576 | 83.103 | 125.537 | 149.109 |
| 95% | 4.437 | 74.680 | 96.302 | 89.500 | 121.248 | 138.921 | 153.509 |

## 3 Test result analysis

### *3.1 Influence of the Admixture Agent on the Water Ratio Limit*

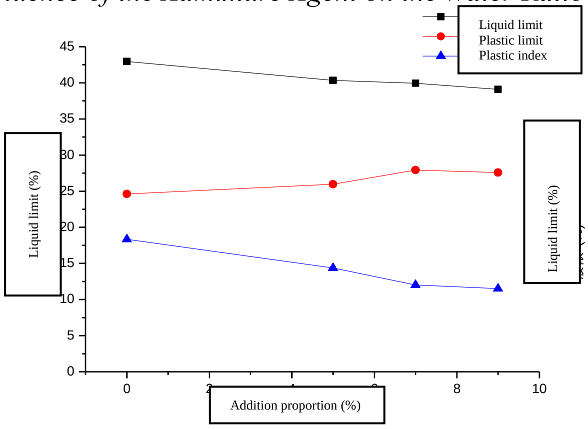


**FIGURE 1.** Influence of Lime Addition proportion on Water Ratio Limit of Red Sandstone

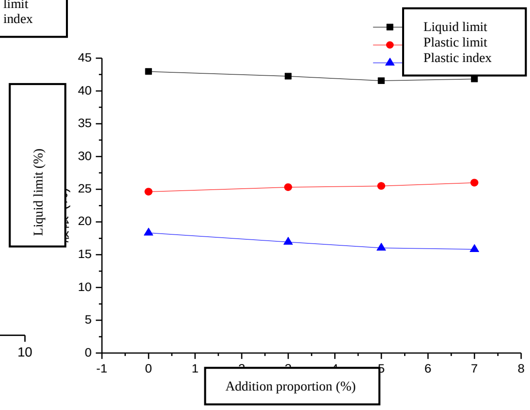


**FIGURE 2.** Influence of Cement Addition proportion on Water Ratio Limit of Red Sandstone

It can be seen from Table 1 that, compared with plain soil, liquid limits of the improved red sandstone after addition of lime and cement decrease, and the plastic limits increase, and the plastic indexes decreases, and there is significant changes on water ratio limit. According to Figure 1, the liquid limit of the red sandstone after improvement with lime gradually decreases with the increase of the admixture agent proportion, and the plastic limit firstly increases and then decreases, and the plastic index gradually decreases. It illustrates that the hydrophilia of the red sandstone after improvement with lime decreases. It can be seen from Figure 2 that, there is no significant change on the plastic limit of the red sandstone after improvement with cement, but the liquid limit is lower than that of the plain soil, appearing in a decline trend, and the plastic limit gradually increases, and the plastic index is in a decline trend.

Generally speaking, the water ratio limits of the red sandstone after improvements with lime and cement change, with improved performance. The performance is improved due to the ion exchange effect between the Ca2+ in the improver and the soil particles, the flocculation and the aggregation effect. On one hand, the ion exchange effect thins the double ionosphere, and weakens the water binding ability, which decreases the hydrophilia[10]. On the other hand, due to the flocculation and the aggregation effect, the small soil particles coagulate into large ones, and the quantity of the small soil particles reduces, which is equivalent to change the proportion of the clay fraction in an artificial way[11]. Therefore, the water ratio limit of the red sandstone after addition of admixture agent is improved.

*3.2 Influence of the Admixture Agent on the Compaction Characteristics*

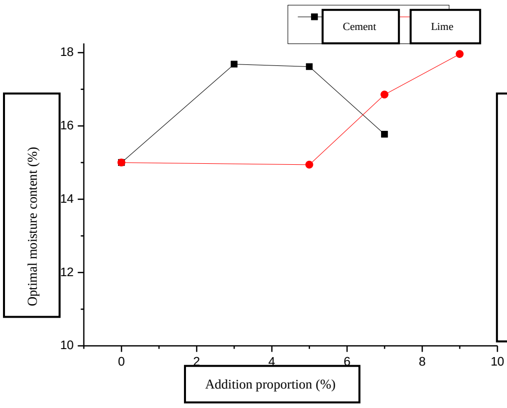


**FIGURE 3.** Influence of the Admixture Agent on the Optimal Moisture content of Red Sandstone

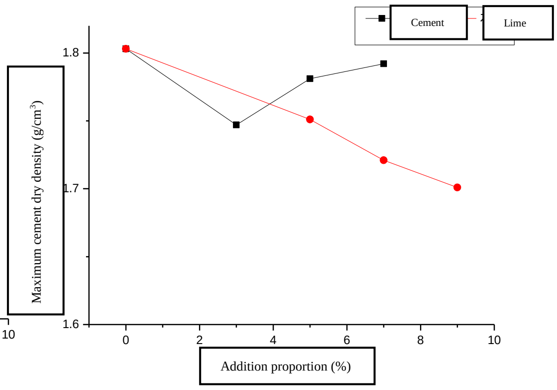


**FIGURE 4.** Influence of the Admixture Agent on the Maximum Dry Density of Red Sandstone

It can be seen from Table 2 that, the maximum dry density of both the lime-improved soil and the cement-improved soil are smaller than that of the plain soil, and with varying patterns. Except for the lime-improved soil with the addition proportion of 5%, the optimal moisture content of the two improved-soils are larger than that of the plain soil, and also with varying patterns.

It can be seen from Figure 2 and Figure 3 that the optimal moisture content of the lime-improved soil gradually increases with the increase of the addition proportion, and is greater than that of the plain soil; the maximum dry density gradually decreases with the increase of the addition proportion of lime, which is consistent with general compaction laws of improved soil. This is mainly related to the mineral compositions of the red sand. After the addition of the lime improver, on one hand, the lime absorbs a part of moisture during the hydration process; on the other hand, the fine particles increase and the specific area increases after the addition of lime due to its large fineness, and it consumes a part of moisture[12] to reduce the friction between soil particles; therefore, the optimal moisture content increases with the increase of the addition proportion of lime.

As for the cement-improved soil, the admixture agent appears different laws on the influence on the compaction characteristic of red sandstone. Different addition proportions of cement lead to different optimal moisture contents and the maximum dry densities; with the increase of the addition proportion, the optimal moisture content of the cement-improved soil gradually decreases, but is larger than that of plain soil, which is different from general acquaintance. The maximum dry density gradually increases with the increase of the addition proportion. It may be caused by the exchange effect between Ca2+ and the positive ion on surface of soil particles after hydration due to the addiction of cement; the Ca2+ replaces the monovalent positive ion, which thins the water film on surface of soil particles and weakens the lubrication action of water on soil particles, to make soil easy for compaction, and increase the dry density.

### *3.3 Influence of Admixture Agent on CBR*

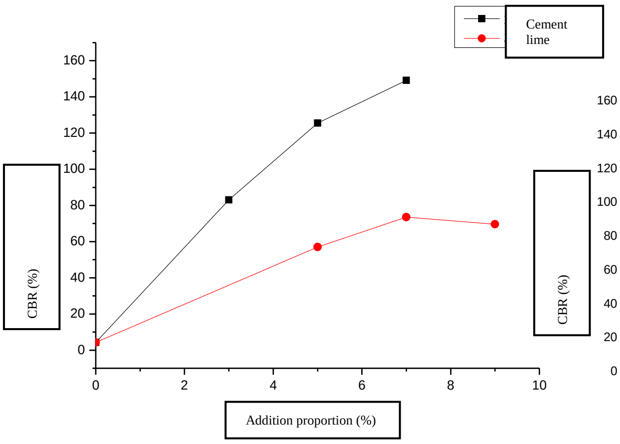


**FIGURE 5.** Influence of Admixture Agent with 93% Compaction on Red Sandstone

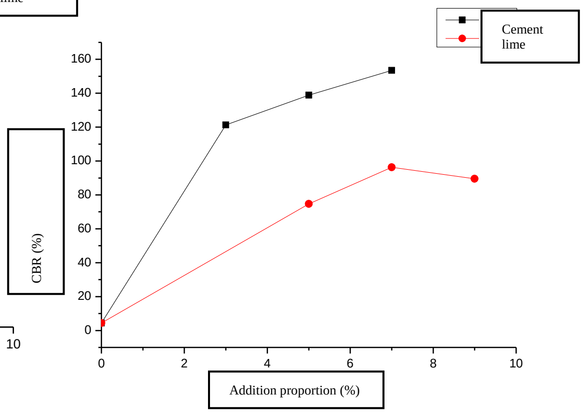


**FIGURE 6.** Influence of Admixture Agent with 95% Compaction on Red Sandstone

Figure 5 and Figure 6 appear the varying patterns of CBR with different types of admixture agents and addition proportions. The CBR of the plain soil is very small, under 5%; Figure 5 and Figure 6 illustrate that the CBR values of the lime-improved soil and the cement-improved soil after improver greatly increase than that of the plain soil. It is caused by the flocculation and the carbonation effect between the soil particles and the improver after the addition of improver. On one hand, due to hydration between lime and cement, it consumes a part of moisture, and it accelerates the evaporation of moisture in soil due to the reaction and heat release of lime, to improve the soil property[13]. On the other hand, the aggregation effect caused by hydration of lime and cement as well as the carbonation effect block the gap between soil clusters, which increases the soundness of soil, and increases soil strength, and increases the CBR of the improved soil[14].

It can be seen from Figure 5 and Figure 6 that, the CBR of lime-improved soil firstly increases and then decreases with the increase of the addition proportion. It illustrates that there is an optimal added quantity for lime; when the addition proportion is increased to certain degree, there will be free lime in soil particles, which decreases the improved soil strength, leading to smaller CBR. The CBR value of the cement-improved soil increases with the addition proportion of cement; in which the CBR value increases in a rapid way when the addition proportion is relatively small; with the increase of the addition proportion, the increase rate slows down. At the same time, it can be seen that the CBR value of the cement-improved soil is larger than that of the lime-improved soil, illustrating that cement has a preferable improvement effect than that of lime.

### *3.4 Influence of Compaction Degree on CBR*

In order to reflect the influence of the compaction degree on the CBR of red sandstone, the influencing curve of the influence on the compaction degree on red sandstone is drawn, as shown in Figure 5 and Figure 6. According to Figure 5 and Figure 6, the CBR values of plain soil under the two compaction degrees are almost the same, illustrating that the only increase of the compaction degree fails to have a preferable effect on the plain red sandstone. As for the lime-improved soil, the compaction degree is increased from 93% to 95%, by taking the addition proportion of 5% as the example, the CBR value increases by almost 30%; as for the cement-improved soil, by taking the addition proportion of 3% as the example, the CBR value increases by 50%. It illustrates that, compared with the plain soil, the increase of compaction function on the improved soil has a more significant effect on the increase of the CBR value.

## 4 Conclusion

(1) Lime and cement have varying influence rules on the compaction characteristic of red sandstone.

The optimal moisture content of the lime-improved soil gradually increases with the increase of the addition proportion, but the dry density gradually decreases; the maximum dry density of the cement-improved soil increases with the increase of the addition proportion, and the optimal moisture content decreases, which is different from general laws on improved soil.

(2) Lime and cement have similar improvement effects on the CBR value of red sandstone, in which cement has better improvement effect than that of lime; it achieves the optimal effect when the addition proportion is 7%; there is also an optimal addition proportion on CBR of the lime-improved soil, and it achieves the optimal value when the addition proportion is 7%; it is necessary to reasonably select the addition proportion according to construction conditions and economic conditions.

(3) As for the red sandstone without improvement, the method of increasing compaction function cannot achieve a significant effect on the increase of the CBR value, and the method of adding admixture agent shall be adopted to improve its DBR value.

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