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Study on Mechanical Properties of Clay Mixed with Construction Waste and Lime Powder

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Abstract*: Clay is widely distributed in Yiyang City. Due to its low strength and great influence on construction safety, clay needs to be improved and reused in actual projects, which leads to problems such as increased construction cost and delayed construction period. In this paper, construction waste, lime powder and clay are mixed according to a certain proportion, so as to improve the strength of soil and reduce construction costs. It is found that construction waste can improve the ductility of soil, but it has no obvious effect on the improvement of compressive strength of soil. When 20% construction waste and 4% lime powder are added, the compressive strength of soil is improved most obviously.
***Keywords*: clay, construction waste, lime powder, strength of soil, mechanical properties**

I. INTRODUCTION

Since the reform and opening up, China's rapid economic development, infrastructure construction is also increasingly perfect, but the resulting types of construction waste is also increasing. According to the calculation of China Urban Environmental Sanitation Association, the annual output of construction waste in big cities in China has exceeded 2 billion tons in recent years, but the recycling rate is less than 10%. These construction wastes not only cause waste of resources and increase the burden on enterprises, but also have adverse effects on the environment. How to utilize construction waste reasonably can alleviate the shortage of materials, reduce the construction cycle and cost, reduce the direct landfill amount of construction waste, reduce the occupation of land, reduce the pollution of various harmful substances in construction waste to the environment, etc.

Yiyang City is located in the central and southern part of China, where a large amount of clay is widely distributed. Due to the low strength of clay, it is easy to cause adverse consequences such as uneven settlement of buildings, so the foundation soil should be improved during the design and construction process. At present, a large number of scholars have conducted research in this field. Zhao Runtao [1] uses chemical modifiers to improve clay, and achieves improvement effect by adding cement and lime in different proportions. The final results show that the improvement effect is remarkable. Wang Bingjie et al.[2] investigated the moisture content and dry density changes of the improved soil under dry-wet cycle conditions by adding gypsum and cement to the soft clay. The test results showed that the water stability of the clay was significantly improved. Long Ningbo et al.[3] investigated the dynamic characteristics of clay improved by adding cement-fiber, and the results showed that the maximum dynamic elastic modulus of improved clay increased significantly, damping ratio decreased significantly, dynamic failure mode changed, and dynamic strength increased significantly. Yang Dezhong et al.[4] studied the pavement performance of high content phosphogypsum stabilized clay with reference to the design method of lime flyash mixture. The results show that the CBR value of high content phosphogypsum stabilized clay is far greater than that of plain clay, which can meet the requirements of road construction.

In this paper, the original clay is improved by using construction waste debris, and the comparative study is carried out by adding different amounts of construction debris and lime powder. The purpose is to improve the excavation and utilization of cohesive soil in this area, promote the economic development of this area, and serve the construction of this area.

II. MODEL TEST

A. Test Materials

The test soil is taken from the vicinity of the dormitory building in Hunan City University. The soil samples are dried by drying equipment to determine the basic mechanical parameters of the soil samples as shown in Table 1. The building debris used for the test is taken from the demolition site of an old residential area. The construction waste is crushed and ground. It is sieved through a 4.75mm washing sieve. The porous particles are retained and analyzed. The results are shown in Table 2. Calcium carbonate of a certain brand is used for lime. The composition of lime powder is determined before the test. The results are shown in Table 3.

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TABLE I Mechanical Parameters of Sampled Clay

proportion	liquid limit W_L / %	plastic limit / %	plasticity index I_P	optimum water content W_{opt} / %	maximum dry density （g/cm^2）
2.72	46.11	22.25	23	18	1.53

TABLE II Particle Composition of Building Debris

consisting /%			particle size distribution	maximum dry density （g/cm^2）
cement	brick slag	rubble		
54	27	19	2.36-4.75	2.31

TABLE III Composition of Lime Powder

calcium oxide / %	magnesium oxide / %	particle size / mm	active calcium oxide / %
69.56	4.12	＜2	＞32

B. Test Process

Unconfined compressive strength tester shall be used for the test. During the preparation of test pieces, the test scheme shall be determined, the mixture ratio of different content shall be determined, the test pieces shall be numbered, and the test pieces of different ages shall be cured in standard curing room. Refer to specification [5] for unconfined compressive strength test. 50mm (diameter) x 50mm (height) test pieces shall be prepared by press machine, and shall be put into standard curing room (temperature 20±2°C, humidity ≥95%) for curing after demoulding. Standard curing shall be carried out for 7 days. On the last day of the curing period, take out the test piece, and then place it in water at a temperature of 20±2°C. The water level is 2.5cm higher than the surface of the test piece. Conduct immersion test. Take out the test piece after soaking for 24 hours, and remove the surface moisture. In order to reduce the influence of moisture content on test results, the optimal moisture content is taken as the test moisture content; because the content of curing agent will affect the optimal moisture content and maximum dry density, different proportion of content is adopted for compaction test. From the test results, it can be seen that when the content is 8%~12%, the dry density value has the smallest change range, and the content of curing agent is 10% in this test.

III. ANALYSIS OF TEST RESULTS

A. Effect of Construction Waste on Soil Mass

Through comparative analysis of the addition amount of construction waste debris (as shown in Figure 1), the axial stress of construction waste debris increases with the increase of axial strain, and decreases when it reaches the highest peak value. With the increase of construction waste content, the axial strain also increases, and does not show an increasing trend. When the construction waste debris content reaches 15%, the axial stress strain reaches the maximum value. Therefore, when the construction waste debris reaches 15%, a better stress effect can be achieved.

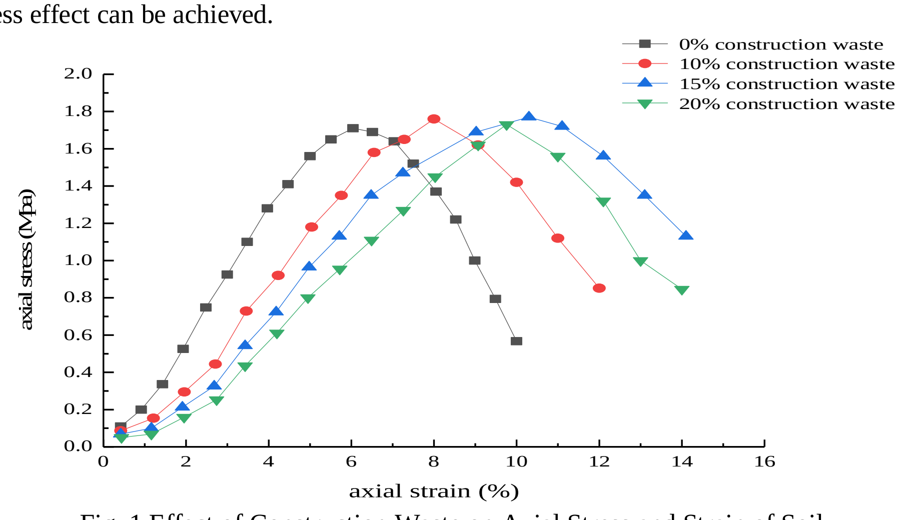

Fig. 1 Effect of Construction Waste on Axial Stress and Strain of Soil

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When the construction waste slag content is constant, explore the influence of age on strength, and use the unconfined compressive strength test to carry out strength test on the specimens with different curing ages. The test results are shown in Figure 2. The compressive strength increases with the increase of construction waste slag content, and the influence of different content on compressive strength at different curing age presents positive correlation, showing an increasing trend. The compressive strength of soil increases greatly with the curing age when the content is 15%, which is the most obvious. Under different curing ages, the best effect can be achieved when the content is 15%. The small particles in the construction waste slag can improve the cohesion and friction of clay, inhibit the development of soil deformation and improve the mechanical properties of soil.

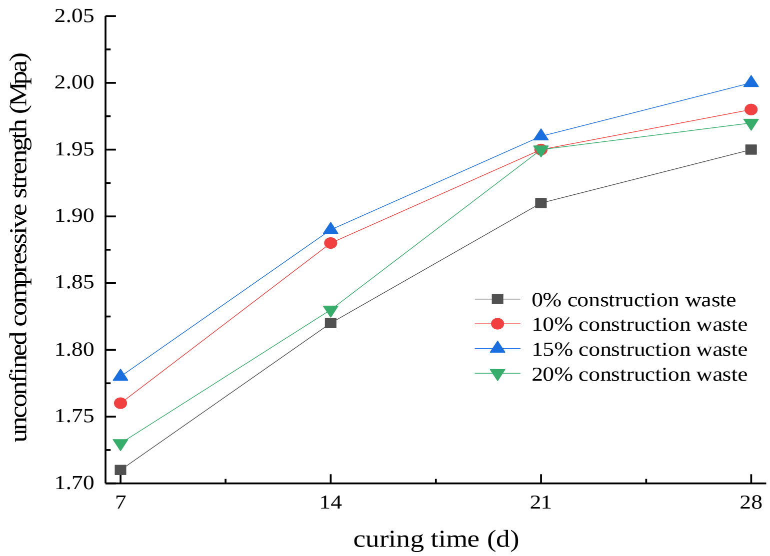

Fig. 2 Effect of Curing Time on Strength

B. *Effect of Lime Powder on Soil*

In order to explore the influence of lime powder addition on clay, the specimen was placed in a standard curing chamber for 7 days. After curing, the specimen was tested for axial stress and strain. The test results are shown in Figure 3. The influence of lime powder on soil firstly increases and then decreases with the increase of axial stress, and with the increase of lime powder content, the axial stress that soil can bear also increases continuously, and the strength of soil added with 5% lime powder increases most obviously; while with the increase of lime powder content, the ability of soil to bear axial strain decreases, and the rate increases in the descending stage, and the soil added with 5% lime powder content is most obvious. This phenomenon shows that although the axial stress of soil is stronger after adding lime powder, the ductility of soil decreases and the brittle failure of soil is more obvious.

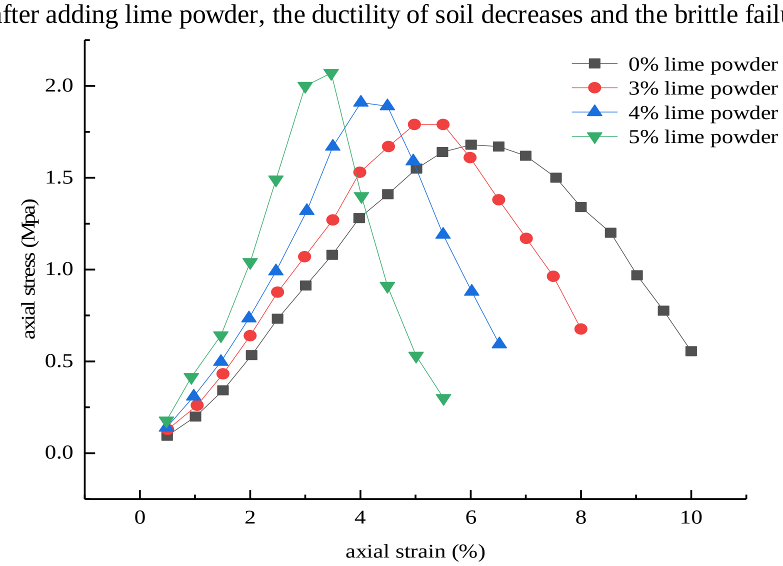

Fig. 3 Effect of Lime Powder on Axial Stress and Strain of Soil

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In order to explore the influence of lime powder on compressive strength, unconfined compressive strength test is used to test the strength of specimens with different curing ages. The test results are shown in Figure 4. The compressive strength of soil mixed with lime powder increases with curing age, and with the increase of content percentage, the compressive strength of soil increases at the same curing age. When the content is 5%, curing age has the greatest effect on compressive strength. In the case of different curing ages, the maximum compressive strength can be sustained when the content is 5%. Therefore, mixing lime powder into soil can effectively improve the compressive capacity of soil and improve the mechanical properties of soil.

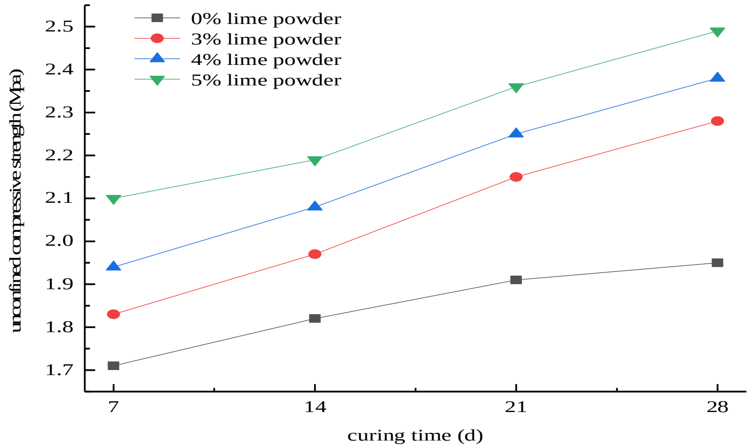
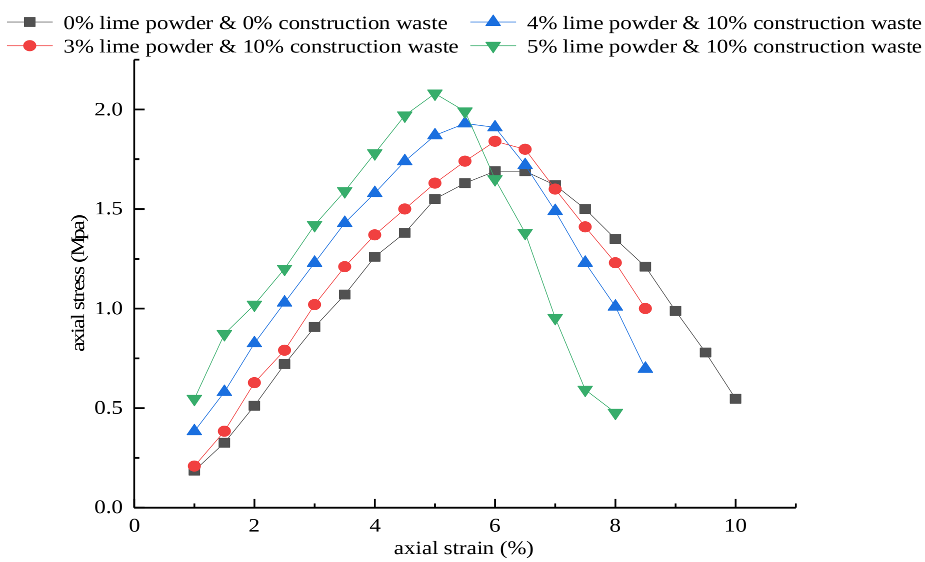


Fig. 4 Effect of Curing Time on Strength

C. Comprehensive Influence of Two Kinds of Admixture on Soil Mass

Comprehensive analysis of the above contents of soil mixed with construction waste and lime powder corresponding to the impact of stress and strain, control the soil sample curing age of 7 days, analysis results as shown in Figure 5. It can be seen from Figure 5 that the axial stress of soil samples mixed with construction waste and lime powder is greater than that of plain soil when the curing period of soil samples is 7 days. When the lime powder is 5% and the construction waste is 10%, the axial stress of soil can bear the maximum; when the lime powder is 5% and the construction waste is 15%, the axial stress of soil can bear the maximum; when the lime powder is 4% and the construction waste is 20%, the axial stress of soil can bear the maximum. When the proportion of construction waste is 10%, the peak value of axial stress of soil sample added lime powder is obviously faster than that of plain soil, and then the decreasing trend is more rapid. When the proportion of construction waste is 15%, this trend slows down. When the proportion of construction waste is 20%, this trend hardly exists, but generally speaking, the time to reach the axial stress limit value is longer than that of plain soil. At the same time, when the lime powder is 4% and the construction waste is 20%, the axial stress of the soil can bear the maximum.



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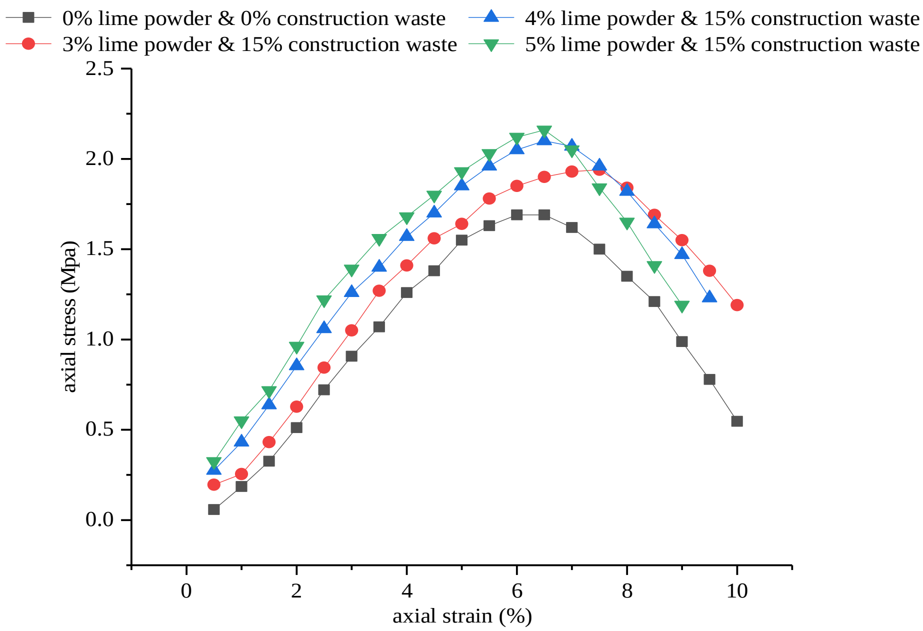

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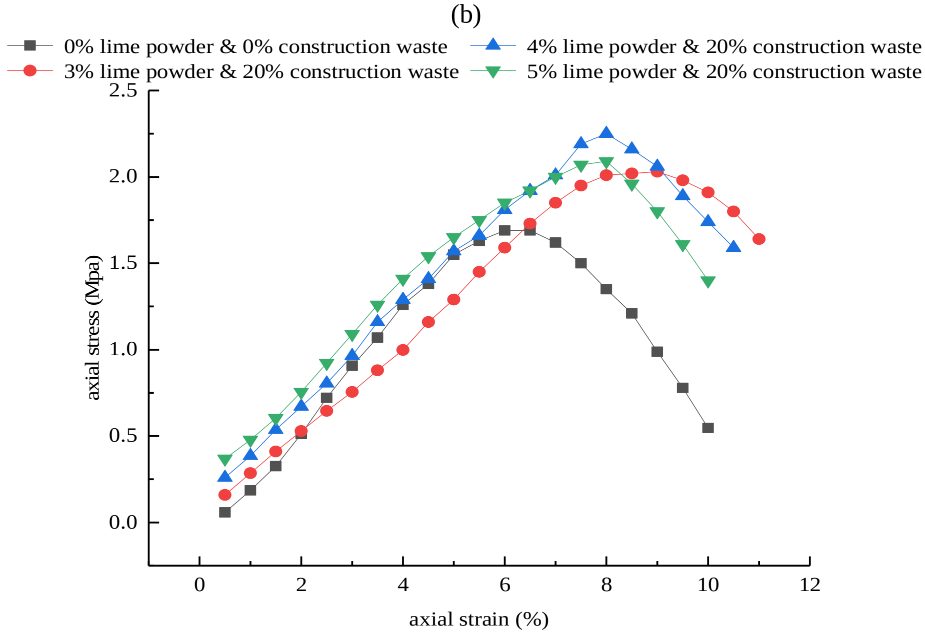
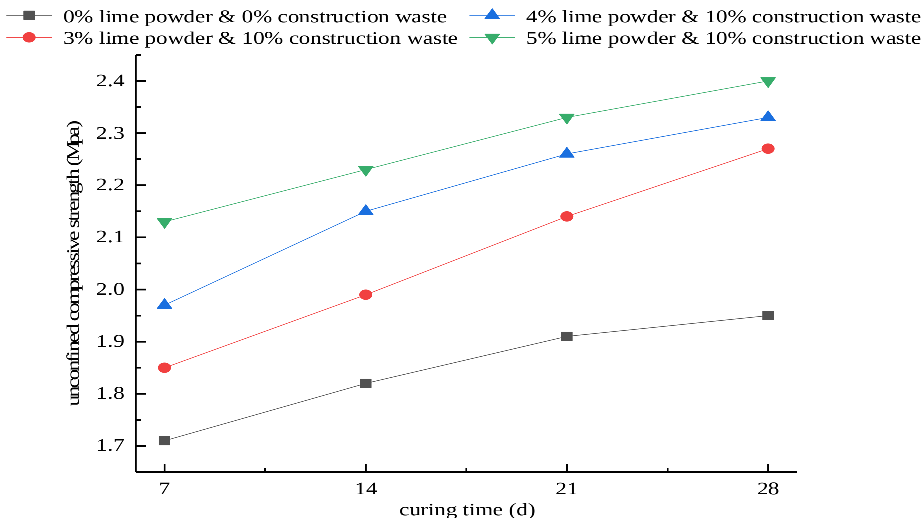


(c)

Fig. 5 Stress-strain Curves of Mixed Soil Samples of Different Proportions of Construction Waste and Lime Powder at 7 Days Curing Time

Fig. 6 Comprehensive analysis of stress-strain variation law of soil samples mixed with construction waste and lime powder in the same proportion at different curing ages. According to the analysis of Figure 6, when the proportion of construction waste is fixed, the higher the lime powder content, the higher the compressive strength of soil mass. However, when the proportion of construction waste reaches 20%, the compressive strength of soil mass containing 4% lime powder is greater than that of soil mass containing 5% lime powder. When the proportion of soil mass mixed with construction waste is fixed, the compressive strength of soil mass increases with the increase of lime powder content, but the improvement is not obvious. Curing age can indeed improve the unconfined compressive strength of soil to some extent, but adding a certain proportion of construction waste and lime powder can improve the unconfined compressive strength of soil more. Overall analysis shows that when 20% construction waste and 4% lime powder are added, the compressive strength of soil increases most.



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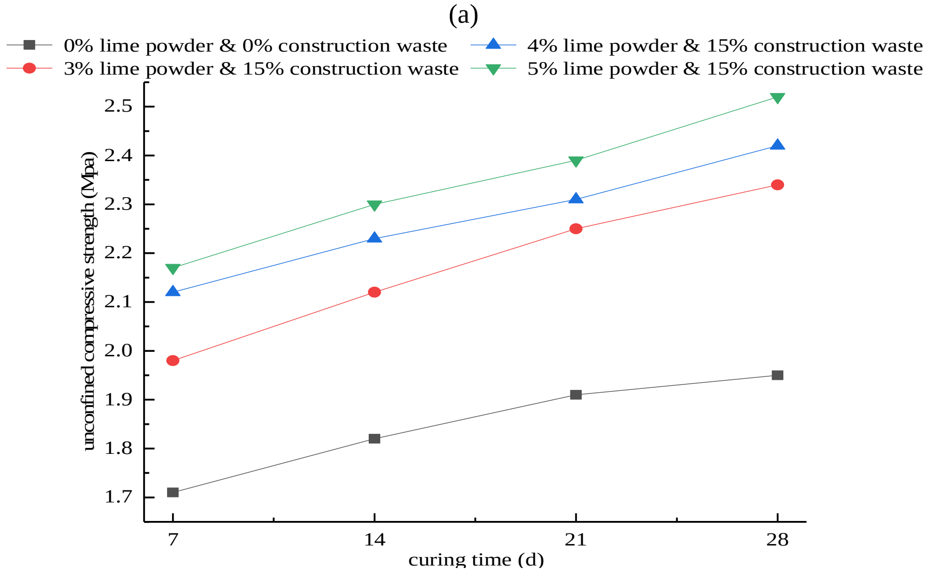

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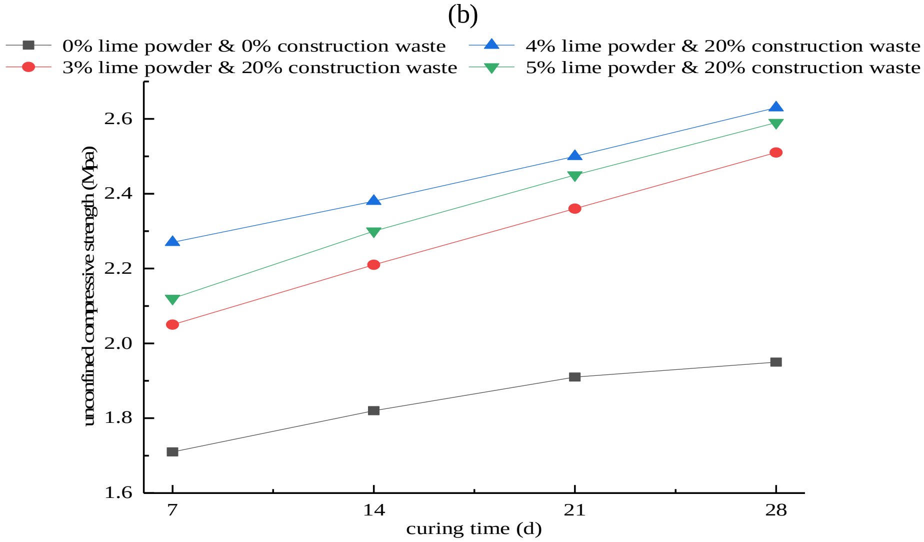

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Fig. 6 Effect of Two Additives on Unconfined Compressive Strength of Soil Samples at Different Curing Time

To sum up, mixing a certain proportion of construction waste and lime powder into soil can effectively improve the unconfined compressive strength of soil, and when mixing 20% construction waste and 4% lime powder, the compressive strength of soil can be improved most, which can be regarded as the optimal scheme. Lime powder can improve the ultimate compressive strength of soil, but reduce the ductility of soil. Mixing construction waste can not obviously improve the compressive strength of soil, but it can make up for the deficiency caused by mixing lime powder. The combination of the two can play a better role.

IV. CONCLUSION

1) Mixing construction waste into soil can not improve compressive strength effectively, but it can improve ductility of soil.
2) Lime powder can improve the unconfined compressive strength of soil effectively, but it will weaken the ductility of soil.
3) The construction waste and lime powder are mixed into the soil. The two additives can complement each other and work together to improve the unconfined compressive strength of the soil.
4) When mixed with 20% construction waste and 4% lime powder, the compressive strength of soil can be improved most. If the curing age can be extended properly, the better effect can be achieved.

In conclusion, mixing a certain proportion of construction waste and lime powder into clay can improve the mechanical properties of clay and provide a new idea for green utilization of construction waste. However, considering the complex environment, schedule requirements, project cost and other factors in the actual project, the research done in this paper needs to be further verified by engineering practice.

V. ACKNOWLEDGMENT

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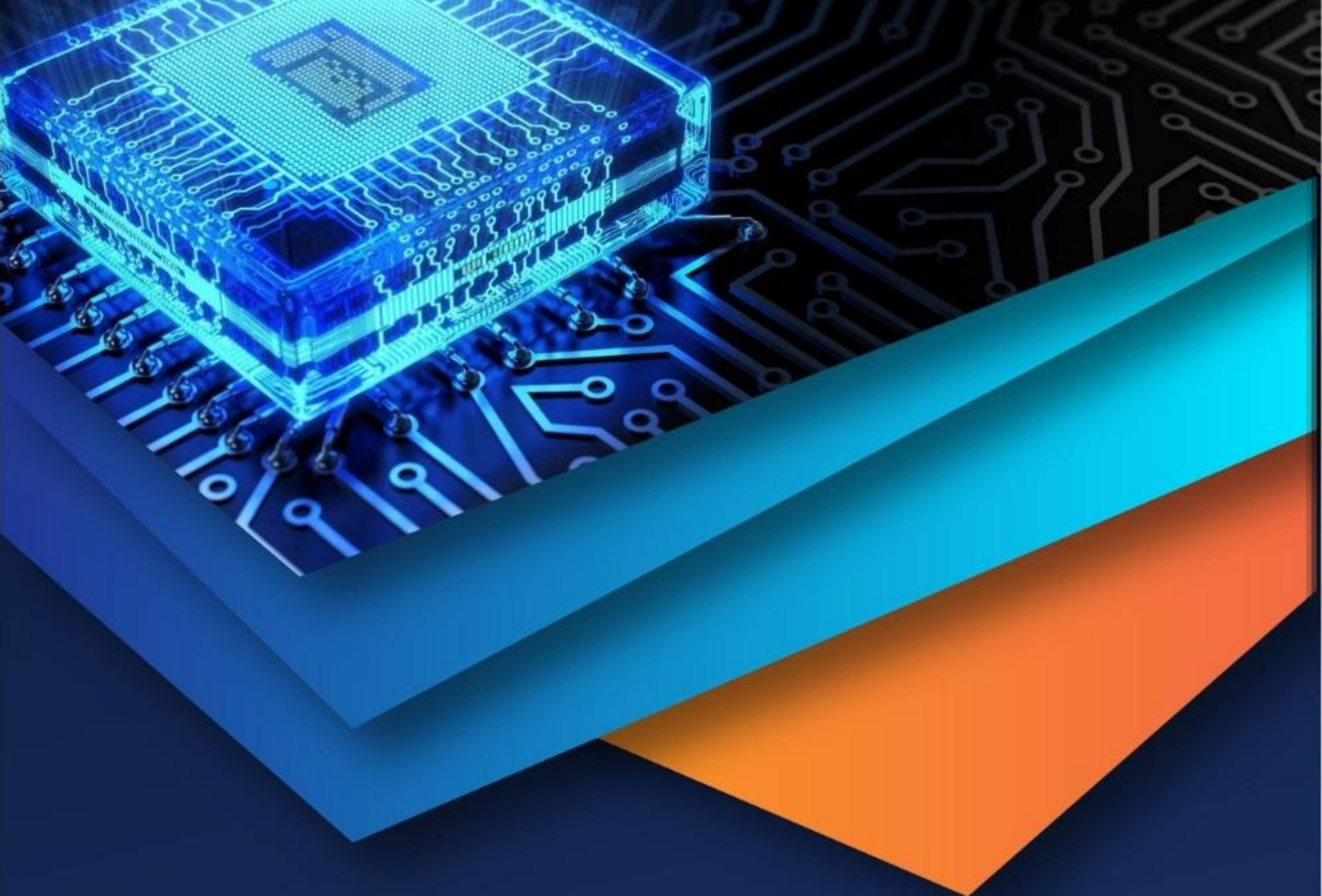

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