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Compressibility of Lime-ash Soil Reinforced by Waste Tire Particles in Large-thickness Collapsible Loess Areas

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Abstract: In this research, an indoor standard compression test of waste tire particles reinforced lime-ash soil is conducted to study the compressibility of the reinforced soil as a foundational material in collapsible loess areas with large thickness. And during this process, the void ratio and compression coefficient of the soil samples with different ages and blending amounts are tested. The research results can be concluded as: (1) The compressibility of waste tire particle reinforced lime-ash soil is better than that of lime soil and plain soil, and thus it can be widely used in large-thickness collapsible loess areas. (2) In all the waste tire particle reinforced lime-ash soil samples, the sample with the blending amount of 30% is superior to the other. Therefore, in making waste tire particle reinforced lime-ash soil, it is suggested to apply the soil with reasonable mix ratio of 30%.

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1. Introduction

The property of loess that collapses rapidly after water soaking under the action of self-gravity or combined action of self-gravity and additional stresses is known as the collapsibility of loess^{[1][2]}. The collapsibility of loess is the major cause of engineering geological disaster in loess areas^[3]. Qingyang City in Gansu Province, located on Dongzhi Yuan, has a loess thickness of less than 200m.

With the rapid growth of economy in Qingyang City, the automobile industry has also seen a dynamic development. And the pollution caused by waste tires, as a result, becomes increasingly serious. Known as a kind of “black solid pollution source”, waste tire degrades slowly in the nature. A large number of waste tires, therefore, have been piled up, occupying cultivated land and destroying vegetation. The long-term stacking is also likely to attract mosquitoes, which may spread diseases and do harm to human health. However, it is of high cost to recycle or reuse these waste tires. They are not suitable to be land filled as solid waste for they are hard to deplete in the nature and hence fire might be caused. If they are treated by incineration, a large amount of toxic gas will be released.

Therefore, the safe handling and recycling of waste tires has become a common concern of scholars at home and abroad. According to incomplete statistics, the United States produces 270 million waste tires per year, and so far up to 300 million waste tires waiting to be treated^[4]. By 2011, China has as many as 10 million tons of waste tires^[5], and the harmless recycling is less than 50%^[6]. Therefore, many domestic and foreign scholars try to apply waste tires in practical engineering.

For example, Li Zhaohui^[7] mixed waste tire strips with loess and applied the mixture as a



lightweight load-relieving material in culverts, effectively reducing the cracking and damage in culverts.

Zou Weilie et al.^[8] applied the waste tires to the improvement of expansive soil and achieved good results; Li Yong et al.^[9] used the waste tire particles modified clay to the liner layer of waste landfill, and found that the properties of the clay liner layer were greatly improved. Cao Weidong et al.^[10] studied the properties of the waste tire rubber modified asphalt through experiments and then discovered the mixture is applicable in paving road. Li Lihua et al.^[11] conducted an indoor research on the prosperities of the slope embankment reinforced with waste tires and the research results show that the bearing capacity of the slope embankment after reinforcement is twice the bearing capacity of plain soil.

In this research, the researcher mixed waste tire particles with loess, fly ash and lime to form waste tire particle reinforced lime-ash soil, and applied the mixture to foundation treatment of large thickness collapsible loess areas to reduce waste tires, protect environment, eliminate the collapsibility of loess and finally improve the bearing capacity of the foundation. In the literature review^[12], the researcher has already made an investigation on the strength, deformation and collapsibility of waste tire particle reinforced lime-ash soil. And in the following sections, the researcher will study the compressibility of the reinforced soil (hereafter, reinforced soil for short) through tests, expecting to verify the applicability of the reinforced soil to foundation treatment in large thickness collapsible loess areas.

2. Test materials and methods

2.1 Test materials

The lime and loess required for this experiment were taken from the project site of a newly-built school in Xifeng District, Qingyang City. The waste tires were purchased from the waste recycling market. After the steel wires were removed, the tires were crushed into particles and sifted with a sieve of 5 mm. The lower part of the sieve was then selected for use. The fly ash was provided by an energy group. The physical properties of the loess required and the waste tire particles required for this experiment are shown in Table 1 and Fig.1, respectively.

Table 1 Physical properties of loess required for the experiment

| Parameters | Water content (%) | Maximum Dry Density (g/cm ³) | Proportion (d _s) | Liquid Limit (w _L) | Plastic Limit (P _L) | Plastic Index (I _p) | Collapse Coefficient (δ _s) | Initial Dry Density (g/cm ³) |
|-------------------|-------------------|--|------------------------------|--------------------------------|---------------------------------|---------------------------------|--|--|
| Mean Value | 22.6 | 1.70 | 2.72 | 25.1 | 16.3 | 8.8 | 0.023 | 1.56 |
| Loess Range Value | 13.6~30.8 | 1.56~1.82 | — | 24.3~26.9 | 14.6~17.3 | 7.2~10.1 | 0.009~0.039 | 1.39~1.75 |



Fig.1 Waste tire particles



Fig.2 Waste tire particle reinforced lime-ash soil sample

2.2 Test methods

The sifted waste tire particles were mixed according to the mixing ratio shown in Table 2, and then mixed and compacted in a compactor, as shown in Fig. 2. In order to simulate the stress conditions of the foundation soil in actual projects, a pit with a depth of 1.5 meters, a length and a width of 3 meters and 2 meters respectively was dug in the open space. And the soil sample prepared by the compactor was placed in the pit. After being placed neatly, the pit was backfilled. After a certain period, a part of the soil samples were excavated for experiment and the remaining soil samples were still buried in the pit.

Table 2 Mix proportion by volume of different samples

| Raw Materials | Mix proportion by volume (%) | | | | | | | |
|----------------------|------------------------------|---------------------------------------|-------------------|-------------------|-------------------|-------------------|-------------------|-------------------|
| | Plain soil | soil with lime and loess ratio of 3:7 | Reinforced soil A | Reinforced soil B | Reinforced soil C | Reinforced soil D | Reinforced soil E | Reinforced soil F |
| Lime | 0 | 30 | 5 | 10 | 4 | 5 | 5 | 5 |
| Fly ash | 0 | 0 | 10 | 10 | 10 | 10 | 10 | 5 |
| Waste tire particles | 0 | 0 | 10 | 30 | 46 | 60 | 70 | 80 |
| Loess | 100 | 70 | 75 | 50 | 40 | 25 | 15 | 10 |

The compression test is carried out in consolidometer. In accordance with the *Standard for Soil Test Method* (GBT50123-1999), the applied loads are 12.5 kPa, 25 kPa, 50 kPa, 100 kPa, 200 kPa, 300 kPa, 400 kPa, respectively. The deformation must be stable (the deformation per hour is not less than 0.01 mm) before the next load can be added. As shown in Fig. 3. The shear strength test is carried out in direct shear apparatus, the applied loads are 12.5 kPa, 50 kPa, 100 kPa, 200 kPa, 300 kPa, 400 kPa.



Fig.3 Standard compression test

3. Results analysis

The physical properties of the samples prepared by the compaction apparatus before the compression test are shown in Table 3 below.

Table 3 Physical properties of samples with different blending amounts

| Index of physical properties | Plain soil | soil with lime and loess ratio of 3:7 | Reinforced soil A | Reinforced soil B | Reinforced soil C | Reinforced soil D | Reinforced soil E | Reinforced soil F |
|------------------------------------|------------|---------------------------------------|-------------------|-------------------|-------------------|-------------------|-------------------|-------------------|
| Density (g/cm^3) | 1.72 | 1.66 | 1.69 | 1.45 | 1.33 | 1.25 | 1.18 | 1.05 |
| Water content (%) | 16.5 | 14.8 | 23.3 | 16.3 | 13.6 | 5.87 | 26.4 | 53.8 |
| Relative density | 2.72 | 2.58 | 2.44 | 2.09 | 1.92 | 1.83 | 1.68 | 1.27 |
| Initial void ratio | 0.84 | 0.78 | 0.78 | 0.68 | 0.64 | 0.55 | 0.80 | 0.86 |

In the following part, the waste tire particle reinforced lime-ash soil Sample A, B, C, D, E and F are abbreviated as Sample A, Sample B, Sample C, Sample D, Sample E and Sample F.

3.1 The correlation between void ratio and pressure

The soil sample with an age of 28d was subjected to a standard compression test. The test results are shown in Fig. 4.

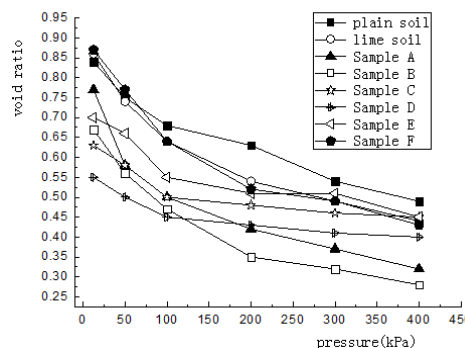


Fig.4 Curve of void ratio under different pressures of 28d soil samples

As can be seen from Fig. 4, with the increase of the pressure, the void ratio of plain soil sample, lime soil sample, Sample A, B, C, D, E and F all decreases. However, in general, the void ratio of Sample A, B, C, D, E and F is smaller than that of plain soil sample and the lime soil sample, indicating that the compressibility of waste tire particle reinforced lime-ash soil is better than that of plain soil and lime soil.

Under the same pressure, the void ratio of Sample B is smaller than that of Sample A, C, D, E and F, which suggests that the compressibility of the reinforced soil with a blending amount of 30% is optimal in the test.

3.2 The correlation between compressive deformation and age

A standard soil compression test was carried out under pressure of 200 kPa on soil samples with ages of 7d, 14d, 28d, 60d, 180d, 360d and 720d respectively. The results are listed in Fig. 5.

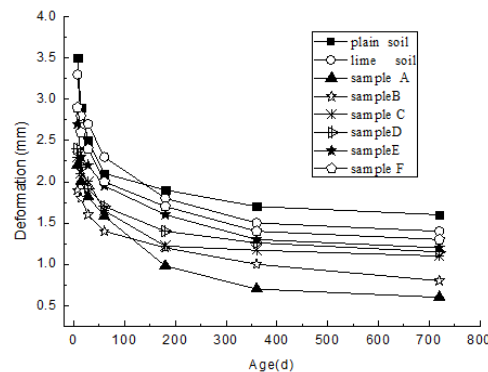


Fig.5 Curve relationship between compressive deformation and age of different soil samples under 200kPa

Fig. 5 shows that with the increase of age, under the pressure of 200kPa, the deformation of plain soil, Sample A, Sample B, Sample C, Sample D, Sample E and Sample F continues to decrease and eventually becomes stable. This demonstrates that the age is also one of the major factors affecting the compressibility of waste tire particle reinforced lime-ash soil.

At the same age, the deformation of Sample A and B is relatively smaller, but in the consolidation compression, the compressibility of Sample B is much stable than that of Sample A, that is, the compressibility of the reinforced soil with a blending ratio of 30% is the best.

3.3 The correlation between void ratio and blending amounts of waste tire particles

A standard compression test was made on Sample A, B, C, D, E and F at age of 28d, with a blending amount of 10%, 30%, 46%, 60%, 70%, and 80%, respectively. And the deformation and void ratio of the soil samples were calculated. The correlation between the void ratio and the blending amount of the waste tire particles under different pressures was finally obtained, as shown in Fig. 6.

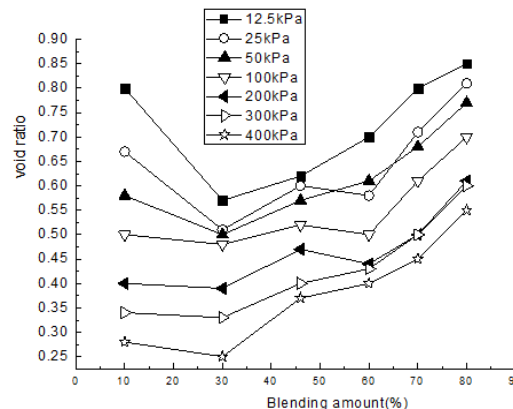


Fig. 6: The curve relationship between void ratio and blending amount of waste tire particles under various pressures

Fig.6 suggests that as the increase of blending amount of the waste tire particles, the void ratio first decreased and then increased, and the void ratio of the reinforced soil with a blending amount of 30% is the smallest.

And meanwhile, with the same blending amount, the larger the pressure, the smaller the void ratio would be. In this sense, the pressure and the blending amount are another two important factors affecting the compressibility of the reinforced soil.

3.4 The correlation between compression coefficient and pressure

A standard compression test was made on Sample A, B, C, D, E and F at age of 28d with a blending amount of 10%, 30%, 46%, 60%, 70%, 80%, respectively. The compression coefficient of the soil samples was calculated, and the correlation between the coefficient and the pressure of the reinforced soil with different blending amounts was obtained, as shown in Fig. 7.

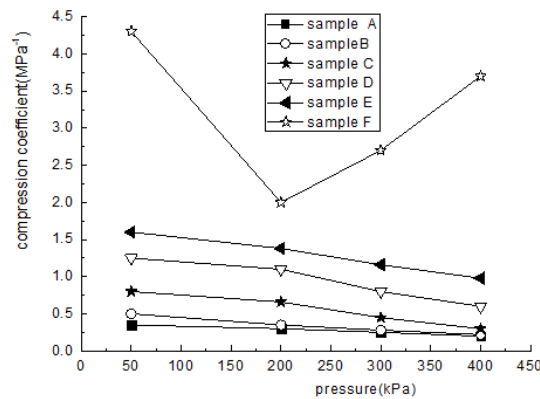


Fig. 7: The curve relationship between coefficient of compressibility and pressure of various blending amounts

Fig. 7 indicates that except Sample F, Sample A, B, C, D and E all decreased in compression coefficient with the increase of pressure. Under the same pressure, the coefficient of Sample A and B are much smaller, suggesting that Sample A and B are more stable in compressibility.

Fig. 7 also reveals that the compression coefficient of Sample A and B is less than 0.5 MPa^{-1} , and that of Sample C, D, E and F is greater than 0.5 MPa^{-1} . Therefore, according to *Code for Investigation of Geotechnical Engineering* (GB50021—2001), the reinforced lime-ash soil with a blending amounts of 10% and 30% are of medium compressibility, and the soil with a blending amount 46%, 60%, 70% and 80% respectively are high in compressibility.

3.5 Correlation between compression coefficient and age

A standard compression test was made on Sample A, B, C, D, E and F at age of 28d, 180d, 360d and 720d with a blending amount of 10%, 30%, 46%, 60%, 70%, and 80% respectively. The compression coefficient of the soil sample was calculated, and the relationship between the compression coefficient and the age of the reinforced soil under 200 kPa was obtained. The curve relationship is shown in Fig. 8.

Fig. 8 demonstrates that except Sample F, Sample A, B, C, D, and E all decreased in compression coefficient with the increase in age. After 360 days, the compression coefficient of Sample A, B and C is less than 0.5 MPa^{-1} , which are of medium compressibility, while the compression coefficient of other soil samples is greater than 0.5 MPa^{-1} , which are high in compressibility.

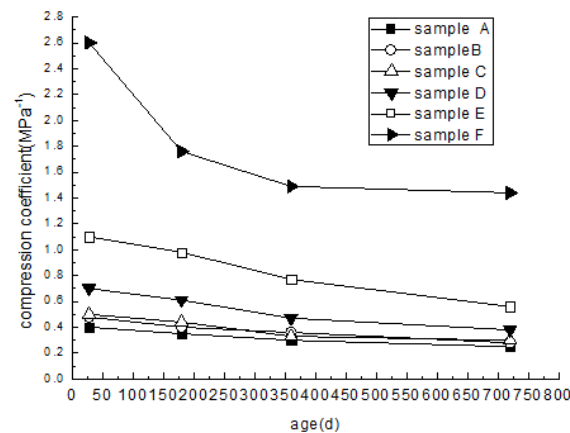


Fig.8 The curve between compression coefficient and age under 200kPa

Fig. 8 also tells that at the same age, under 200 kPa, the compression coefficient of the soil sample gradually increased as the blending amount of waste tire particles increased.

To sum up, the compressibility of the waste tire particle reinforced lime-ash soil is better than that of the lime soil and the plain soil. Out of all samples, the compressibility of Sample B is better than that of other samples. That is, the waste tire particle reinforced lime-ash soil with a blending amount of 30% has the optimal compressibility.

4. Conclusion

(1) The compressibility of waste tire particle reinforced lime-ash soil is much better than that of lime soil and plain soil. Therefore, it can be widely used in foundation treatment in large-thickness collapsible loess areas.

(2) Of all the waste tire particle reinforced lime-ash soil samples, the reinforced soil with the blending amount of 30% is superior to the other samples. Therefore, it is recommended to use reasonable mix ratio when making reinforced soil and the blending ratio is suggested to be 30%.

(3) The amount of tire particles blended, age and pressure are the three main factors affecting the compressibility of waste tire particle reinforced lime-ash soil.

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References

- [1] Liu Zudian. *Loess Mechanics and Engineering* [M]. Xi'an: Shaanxi Science and Technology Press, 1996.
- [2] Qian Hongjin, Wang Jitang, Luo Yusheng, et al. *Collapsible Loess Foundation* [M]. Beijing: China Building Industry Press, 1985
- [3] Zhu Xinghua, Peng Jianbing, Tong Xiao et al. *Study on geological disaster chain in loess area*[J]. *Journal of Engineering Geology*, 2017: 25(1): 117~122.
- [4] Wang Haijin. *Experimental study on mechanical properties and frost resistance of waste tire rubber concrete*. [D]. Beijing: China University of Mining and Technology, 2017.
- [5] He Junfei. 2017. *Effects of Ground Rubber on Compressibility, Shrinkage and Hydraulic Conductivity of Kaolin Soils*[D]. Beijing: China University of Mining and Technology.
- [6] National Development and Reform Commission of the People's Republic of China. 2012. *Annual Report on Comprehensive Utilization of Resources in China* (2012) [R].http: //

- [www.sdpc.gov.cn / xwfb /t20130408_536294.htm](http://www.sdpc.gov.cn/xwfb/t20130408_536294.htm).
- [7] Li Zhaohui. 2011. *Study on geotechnical characteristics of waste tire particles and loess mixture* [D]. Lanzhou: Lanzhou University.
 - [8] Zou Weilie, Xie Peng, Ma Qitian, et al. 2011. *Experimental study on waste tire rubber particles modified expansive soil* [J]. Journal of Sichuan University (Engineering Science Edition), 43(3): 44~48 .
 - [9] Li Yong. 2015. *Study on the properties of waste tire modified clay liner* [D]. Wuhan: Hubei University of Technology.
 - [10] Cao Weidong & Lu Weimin. 2007. *Experimental Research on Recycled Tire Rubber Modified Asphalt Mixture Using Hybrid Process* [J]. Journal of Building Materials, 10(1): 110~114.
 - [11] Li Lihua, Cui Feilong, Xiao Henglin, et al. 2017. *Performance and bearing capacity of embankments reinforced with waste tires and geocells* [J]. Chinese Journal of Geotechnical Engineering, 39(1): 81~88.
 - [12] Yan Tiecheng, Zhang Xingyuan. 2018. *Comparative study on engineering performance of waste tire particles and 3:7 lime soil* [J]. Engineering Investigation, 7:1~4.