Experimental study of working performance and mechanical properties to rubber with limestone powder concrete

Z F Zhao¹, X Z Zhang¹, L F Li¹ and Y Yang²

¹ School of Civil and Architectural Engineering, Guizhou University of Engineering Science, Bijie, Guizhou, 551700, China
² College of Civil Engineering, Longdong University, Qingyang, Gansu, 745000, China

*Corresponding author’s e-mail: zzfchaoyue123@163.com

Abstract. The influence of limestone powder concrete on working performance and mechanical properties are researched under which it is changed substitution rate of rubber powder and mixing ratio of rubber powder with different fineness under equal substitution rate. Take C30 concrete as an example, two proportioning schemes are set respectively: The machine-made sand of limestone powder concrete is replaced by 20 mesh rubber powder equal volume; Under the specific constant volume rate of substitution, changing the mixing ratio of 20 and 40 mesh rubber powder to research working performance and mechanical properties of concrete. The results show that the substitution rate of 20 mesh rubber powder is less than 10%, increasing the slump of concrete. On the contrary, the slump of concrete decreases sharply and the flow performance weakens. The compressive strength of concrete decreases sharply when increasing substitution rate of 20 mesh rubber powder. When increasing the mix ratio of 20 and 40 mesh rubber powder under equal substitution rate, the slump of concrete increases and the compressive strength increases first and then decreases. Fixing the mixing ratio, the slump and compressive strength decrease with the increase of rubber powder substitution rate. When the mixing ratio of 20 and 40 mesh rubber powder is 2:1, the compressive strength of concrete is higher.

1. Introduction

With the development of automobile industry and the improvement of people's living standard[1], the popularity of automobile as a comfortable and safe means of transportation in people's life is increasing year by year. When cars meet people's traffic needs, the waste rubber tires not only are large in quantity, but also cause greater pollution to the environment (according to statistics, in 2015, the number of used rubber tires in China reached about 300 million, with an annual growth rate of 8%-10%)[2,3].

A new type of concrete material is formed by replacing coarse and fine aggregate in cement concrete with rubber powder particles of different particle sizes according to a certain proportion and equal quality. Rubber concrete has the characteristics of light weight, sound insulation and heat preservation, strong durability, impact resistance and good ductility[4,5].

Scholars at home and abroad have done a lot of research on the working and mechanical properties of rubber concrete, and have achieved fruitful results[6,7,8]. The focus of the research is to study the performance of concrete based on ordinary concrete, rubber powder instead of aggregate or cement-
based cementitious materials in concrete[9,10,11,12]. There are few reports on the properties of rubber-limestone concrete.

Limestone powder concrete is a new type of engineering composite material developed by using limestone powder as the main mineral admixture. Limestone resources are abundant in Guizhou. The technology of making mechanical crushed stone, mechanical sand and mineral admixture limestone powder from limestone has become the technical trend of the development of commercial concrete in Guizhou. While reducing the cost of concrete, local materials and waste solid utilization protect the ecological environment.

Compared with ordinary concrete, limestone powder concrete has the advantages of enhanced water reduction and good durability[13,14]. It is widely used in engineering construction in this region and has achieved good economic and environmental benefits. In order to improve the toughness and reduce the dead weight of limestone powder concrete, the work performance and mechanical properties of rubber-limestone powder concrete are studied.

In this paper, the working performance and mechanical properties of rubber-limestone powder concrete are researched through experiments. Take the mixture ratio of C30 concrete as an example. In the test, 40 mesh and 20 mesh waste tire rubber powder are used, and four kinds of rubber powder are set equal volume to replace machine-made sand in limestone powder. Substitution rate operating conditions are: 0%, 10%, 20%, 30%. By changing the particle size and mixing amount of rubber powder in each working condition, the working performance and mechanical properties of rubber-limestone powder concrete are studied. It provides reference for the practical application of rubber-limestone powder concrete engineering.

2. Raw material and test design

2.1. Raw material condition
Cement: PO42.5 cement from Guizhou Bijie Jiangtian Cement Co., Ltd., fineness 4%, standard consistency 26.3%, initial setting time 175 min, final setting time 225 min, fluidity 235 mm, 3-day flexural strength 5.9MPa, compressive strength 31.7MPa.

Gravel: high-quality mechanical limestone gravel of Guizhou Rock High-Tech New Material Co., Ltd., particle size 5-22mm continuous grading, apparent density 2718 kg/m³.

Sand: high-quality mechanized sand from Guizhou Rock High-Tech New Material Co., Ltd., with fineness modulus 3.4, moisture content 2.1%, Mb value 1.0, and apparent density of 2736 kg/m³.

Stone powder: mechanized limestone powder from Guizhou Rock High-Tech New Material Co., Ltd., with 86% calcium carbonate and 10% fineness, other technical indexes meet the requirements of the regulations.

Rubber powder: Use 40 mesh and 20 mesh rubber powder. Water: city tap water.

Water reducing agent: 9% low concentrated carboxylic acid water reducing agent from Guizhou Kezhijie Co., Ltd.

2.2. Experimental design
Take the example of C30 concrete, the mixture ratio is: cement 260Kg, gravel 955Kg, sand 910Kg, stone powder 90Kg, water 170Kg, admixture 6.3kg, apparent density 2391.3 kg/m³.

The experimental design is divided into three aspects:
- Using 20 mesh rubber powder equal volume instead of mechanical sand, the replacement rates of the four working conditions are 0%, 10%, 20% and 30% respectively. The variation of concrete performance and strength characteristics with the substitution rate of rubber powder is studied. The dosage ratio is shown in Table 1.
- The substitution rate is constant, studying the influence of the working performance and mechanical properties of concrete when the rubber powder different proportions and the change of rubber powder particle size. The specific mixing amount and ratio is shown in Table 2.
As the replacement rate increases, 20 mesh and 40 mesh rubber powder are mixed in the same proportion, the working performance and strength characteristics of concrete are studied. The specific mixing amount and ratio is shown in Table 2.

Mold according to the standard method of mixture sampling. Specimen size is 150mm x 150mm x 150mm, timely into the standard maintenance room for maintenance for 28 days and number. Then, Dye-2000 concrete pressure tester is used to test the compressive strength.

Table 1. Mix proportion of 20 mesh rubber powder equal volume replacement machine-made sand (unit: Kg/m³)

| Equal volume replacement rate | Specimen number | Rubber powder | Limestone powder | Mechanisms sand | Graded crushed stone | Cement | Water | Admixtures |
|------------------------------|----------------|---------------|-----------------|----------------|---------------------|--------|-------|------------|
| 0                            | 1-1            | 0             | 90              | 910            | 955                 | 260    | 170   | 6.3        |
| 10%                          | 2-1            | 37.1          | 90              | 819            | 955                 | 260    | 170   | 6.3        |
| 20%                          | 3-1            | 74.2          | 90              | 728            | 955                 | 260    | 170   | 6.3        |
| 30%                          | 4-1            | 112.2         | 90              | 637            | 955                 | 260    | 170   | 6.3        |

*Description: A stands for 20 mesh rubber powder, B stands for 40 mesh rubber powder

Table 2. Mix proportion of concrete with equal substitution rate and different fineness rubber powder (unit: Kg/m³)

| Emplacement rate | Specimen number | Rubber powder percentage (A/B) | Rubber powder | Mechanisms sand | Cement | Limestone powder | Graded crushed stone | Water | Admixtures |
|------------------|----------------|-------------------------------|---------------|----------------|--------|------------------|----------------------|-------|------------|
| 0                | 1-1            | —                             | —             | —              | 910    | 260              | 90                   | 955   | 170        | 6.3        |
| 10%              | 2-1            | 1:1                           | 18.6          | 18.6           |        |                  |                      |       |            |            |
| 2-2              | 2:1            | 24.7                          | 12.4          | 819            | 260    | 90               | 955                 | 170   | 6.3        |
| 2-3              | 3:1            | 27.8                          | 9.3           |                |        |                  |                      |       |            |            |
| 20%              | 3-1            | 1:1                           | 37.1          | 37.1           |        |                  |                      |       |            |            |
| 3-2              | 2:1            | 49.5                          | 24.7          | 728            | 260    | 90               | 955                 | 170   | 6.3        |
| 3-3              | 3:1            | 55.6                          | 18.6          |                |        |                  |                      |       |            |            |
| 30%              | 4-1            | 1:1                           | 56.1          | 56.1           |        |                  |                      |       |            |            |
| 4-2              | 2:1            | 74.8                          | 37.4          | 637            | 260    | 90               | 955                 | 170   | 6.3        |
| 4-3              | 3:1            | 84.2                          | 28.0          |                |        |                  |                      |       |            |            |

*Description: A stands for 20 mesh rubber powder, B stands for 40 mesh rubber powder

3. Analysis of test results
In accordance with "Standard for Test Methods of Performance of Ordinary Concrete Mixture" (GB/T50080-2016). Weighing the material according to the mix ratio in Table 1 and Table 2 as shown. Put the well-weighed gravel, machine-made sand, cement, stone powder and rubber powder into the mixer in turn. After 60 seconds of dry mixing, the water with a certain proportion of water-reducing agent is evenly and slowly added into the mixer. After stirring for 2min, pour the mixture out of the mixer and mix it manually with a spade for 30s. Test slump according to specification.
The influence of 20-mesh rubber powder substitution dosage on slump is shown in Figure 1: With the increase of 20-mesh cement powder substitution content, the slump of concrete increases first and then decreases. When the amount of rubber powder is less than 10%, the slump of concrete shows an increasing trend, and the flow performance of the mixture is good. When the substituting dosage is 10%, compared with the concrete without rubber powder, the slump growth rate is 57.14%. When the amount of rubber powder is more than 10%, the slump of concrete decreases linearly. When the replacement rate is 20% and 30% respectively, the concrete slump is compared with that of rubber powder mixing amount of 10%, the rates of decline are respectively 23.6% and 47.3%. Limestone powder in concrete has a certain inert and reducing water effect, rubber powder itself has the characteristics of fast water absorption, water absorption rate.

Figure 2 shows the influence of powder dosage of different fineness on slump under constant volume substitution: When the substitution rate of rubber powder is constant, the mixing proportion of 20 mesh and 40 mesh rubber powder increases, concrete slump overall shows an increasing law. When 20 mesh glue powder and 40 mesh glue powder mixed with a certain proportion, increasing substitution ratio of rubber powder, slump decreases and the mobility of concrete is reduced. It shows that the fineness of rubber powder has a great influence on the flow performance of concrete, the flow performance of concrete increases with the increase of particle size and the flow performance decreases when the particle size decreases.

Figure 3 shows: The compressive strength of concrete decreases with the increase of 20-mesh rubber powder substitution rate. When the substitution rate of rubber powder exceeds 20%, the
The compressive strength of concrete began to decline sharply. The compressive strength of concrete without mixing powder is 34.4 MPa. When the replacement rates are respectively: 10%, 20% and 30%, the strength of concrete are 29.5MPa, 24.6MPa and 14.5MPa. Compared with the compressive strength of concrete without rubber powder, the reduction rate of the concrete compressive strength are 14.2%, 28.4% and 57.8%.

The results in Figure 4 show that:

- Under the premise of a certain substitution rate, the compressive strength of concrete increases firstly and then decreases with the increase of 20-mesh and 40-mesh adhesive powder mixing ratio.
- The compressive strength of concrete decreases with the increase of the substitution rate of rubber powder when the mixing proportion of different fineness powder is constant.
- When the mixing ratio of 20-mesh cement powder and 40-mesh cement powder is 2:1, the overall compressive strength of concrete is higher than that of 1:1 and 3:1 with different fineness ratios. It can be seen that when the mixing ratio of 2:1 with different fineness is 2:1, the internal porosity of concrete is smaller, and the filling effect improves the compressive strength of concrete.

4. Conclusions

- When 20 mesh rubber powder substitutes machine-made sand by equal volume less than 10%, the slump of concrete increases and the flow performance is good. When the replacement rate is greater than 10%, the working performance of concrete decreases sharply. The compressive strength of concrete decreases with the increase of the substitution rate of 20-mesh rubber powder.
- At the rate of equal substitution, as the mixing ratio of 20-mesh and 40-mesh rubber powder increases, slump increases. When 20 mesh glue powder and 40 mesh glue powder mixed with a certain proportion. With the increase of substitution ratio of rubber powder, the slump decreases and the flow performance weakens, the compressive strength increases first and then decreases.
- When different fineness of powder mixed with a certain proportion, The compressive strength decreases with the increase of the substitution ratio of rubber powder. When the mixing ratio of 20-mesh adhesive powder and 40-mesh adhesive powder is 2:1, the micro voids in concrete are reduced, and the filling effect improves the compressive strength of concrete.

Acknowledgments
This study was financially supported by Young Science and Technology Talents Growth Project of Education Department of Guizhou Province (Q, J, H. KYZ[2017]307) and Research Project of Universities, Provincial Department of Education, Gansu, China (2020B-219).

References
[1] Liu, Y.G. (2010) Research progress of rubber concrete properties. Synthetic Materials Aging and Application., 04: 83-87.
[2] Wang, L.L, Jian, Y.Q, Tong, D.W, Dai, W.M. (2018) Research progress of rubber concrete. Technology of Highway and Transport., 01: 17-20.
[3] Youssf, O, Hassanli, R, Mills, J.E. (2017) Mechanical performance of FRP-confined and unconfined crumbrubber concrete containing high rubber content. Journal of Building Engineering., 11: 115-126.
[4] Zhou, F.L., Zhao, J.Y., Yang, G.L. (2018) Study on the influence of the amount of rubber powder on the basic properties of concrete, Concrete., 01: 72-75.
[5] Xiong, J., Zheng, L., Yuan, Y. (2004) Experimental study on compressive strength of waste rubber concrete. Concrete., 12: 40-42.
[6] Yang, C.F., Yang, M., Wu, W.H. (2013) Experimental study on working performance of waste rubber concrete. Concrete., 05:83-86+92.
[7] Tian, Y.F., Li, Z.C., Gao, Y.Q. (2015) Experimental study on permeability of concrete modified by waste rubber powder. China Concrete and Cement Products., 09: 86-89.
[8] Chen, A.J., Han, X.Y., Wang, Z.H., Li, X.H. (2018) Experimental study on mechanical properties of modified rubber concrete. Concrete., 05: 91-93+97.

[9] Zhang, J., Hu, Y.L. (2020) Experimental study on compression size effect of rubber concrete with different substitution rates. Bulletin of the Chinese Ceramic Society., 01: 106-112.

[10] Xiang, J. (2017) Study on application of limestone powder in high performance concrete. In: Ecological Entomology. Concrete., 01: 150-152.

[11] Hu, J., Stroeven, P. (2004) Properties of the interfacial transition zone in model concrete. Interface Science., 04 : 389-397.

[12] Gao, Y., Deschutte, R.G., Ye, G., et al. (2013) Characterization of ITZ in ternary blended cementitious composites experiment and simulation. Construction and Building Materials., 41: 742-750.

[13] Liu, R.X., Hou, W.S., Xu, Y. H., et al. (2009) Effect of crumb rubber on the mechanical properties of concrete. Journal of Building Materials., 03 : 341-344 (in Chinese)