The Mechanical Properties Analysis of New Rubber Concrete

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Abstract. Rubber cement-based material is a new kind of green material. At present, the research on the influence of rubber on the properties of cement-based materials has obtained some qualitative results (the addition of rubber can reduce the strength and elastic modulus of materials, but can improve the cracking performance of cement-based materials). But the research of the existing rubber mechanism analysis how to affect the performance of cement base material is not clear, as the research object, this article selects the rubber concrete combination of microscopic, mesoscopic and macroscopic, from the mesoscopic level, based on the composite elastic modulus prediction model, at the same time considering the rubber and the effect of pore rubber concrete elastic modulus prediction formula is established; From the macro level, the rubber concrete compressive strength, bending, split strength, modulus of elasticity drying shrinkage and crack resistance test and research, and analyzed the related theory, based on binary complex modulus of elasticity and calculation model, the equations of the elastic modulus of rubber cement mortar prediction formula, explains the difference of the rubber particle size effects on the mechanical properties of cement mortar, the rubber to reduce the mechanical properties of cement mortar in addition because of its "soft" characteristics.

1. Introduction

The addition of rubber will reduce the strength of cement-based materials, which is the consensus of researchers. It is also the main weakness of rubber cement-based materials. At present, the mechanism of rubber reducing cement-based material strength is analyzed, mainly considering that the incorporation of rubber into cement-based material introduces flexible material, thus reducing its strength. Studies have shown that the addition of rubber will introduce a large number of pores into cement mortar. For example, in the mixture ratio sample of m-50%-RC group, the volume content of rubber is 27%, but the additional porosity has reached 10.1%. It is well known that an increase in porosity also decreases the strength of the material. At present, the mechanical properties of rubber cement-based materials are considered only by the amount of rubber and the effect of additional porosity introduced by rubber is ignored. Therefore, it can be speculated that the rubber particle size affects the mechanical properties of cement-based materials by influencing their pore structure.

Therefore, on the basis of the existing research, the basic mechanical properties of rubber cement-based materials were studied by taking into account the rubber mixing amount and the additional porosity introduced by it.
2. Another section of your paper

The tensile strength of cement-based materials can be divided into three types: axial tensile strength, splitting tensile strength and bending tensile strength. For cement mortar materials, axial tensile strength is seldom used due to the difficulty of clamping fixture and the easy generation of eccentricity. Therefore, the tensile strength of rubber cement mortar was studied by bending test (three point bending test) and splitting test.

The section of rubber cement mortar specimens in each group after the flexural resistance test is shown in Fig. 1. As the density of sand is about 2.5 times of the density of rubber aggregate, rubber is prone to float in cement mortar. For the traditional cement-based materials, due to the greater fluidity of the mixture and the greater difference in density between the components, the slurry may float up and the aggregate may sink in the mixing process. For rubber-cement-based materials, rubber and cement slurry usually float up and aggregate sinks. In order to solve this problem, the method of controlling vibration time is usually adopted in the mixing process to prevent the rubber from floating or in the process of mixing ratio design, reduce the water consumption or the amount of water reducer to improve the cohesion of the material. As can be seen from the figure 1, the distribution of rubber in cement mortar in the specimen in this paper is basically uniform, without the phenomenon of rubber particles floating up.

![The sectional view of bending specimen](image1)

**Figure 1.** The sectional view of bending specimen

By comparing the data of each group, it can be found that the splitting and breaking strength of rubber cement mortar decrease with the increase of rubber content when the rubber particle size is the same. With the same amount of rubber, the flexural and split tensile strength of rubber cement mortar decreases with the decrease of rubber particle size. When the rubber content is 50%, the 28-day flexural and split tensile strength of mortar mixed with rubber C is the lowest, which is 58.1% and 70.1% lower than that of the reference group M0.

![Breaking and splitting strength of rubber cement mortar](image2)

**Figure 2.** Breaking and splitting strength of rubber cement mortar
3. The reduction coefficient of rubber to fracture resistance and split tensile strength of cement mortar was fitted

Assuming the same water-cement ratio and fine aggregate admixture, the reduction coefficient of rubber incorporation to the bending strength of cement mortar is $\phi_f$, so

$$\phi_f = \frac{\sigma_{f-R}}{\sigma_{f-o}} \quad (1)$$

In the formul $\sigma_{f-R}$ Represents the bending strength of cement mortar mixed with rubber; $\sigma_{f-o}$ Represents the bending strength of plain cement mortar M0. Similarly, the reduction coefficient of rubber addition to the splitting tensile strength of cement mortar is $\phi_s$.

$$\phi_s = \frac{\sigma_{s-R}}{\sigma_{s-o}} \quad (2)$$

In the formul, $\sigma_{s-R}$ Represents the splitting tensile strength of cement mortar mixed with rubber; $\sigma_{s-o}$ Represents the splitting tensile strength of plain cement mortar M0.

In the process of fitting the reduction coefficient, both the rubber volume ratio $\varphi_r$ and the additional porosity of the cement mortar caused by rubber incorporation $\varphi_p$ are taken into account, as shown in the table 1.

### Table 1. Additional porosity in the rubber introduced into the mortar

| SN     | Rubber volume ratio (%) | The total porosity (%) | Additional porosity (%) |
|--------|-------------------------|------------------------|-------------------------|
| M0     | 0                       | 13.6                   | 0                       |
| M-17% RA | 9                      | 15.4                   | 1.8                     |
| M-33% RA | 18                     | 17.4                   | 3.8                     |
| M-50% RA | 27                     | 18.5                   | 4.9                     |
| M-17% RB | 9                      | 16.8                   | 3.2                     |
| M-33% RB | 18                     | 17.7                   | 4.1                     |
| M-50% RB | 27                     | 19.3                   | 5.7                     |
| M-17% RC | 9                      | 16.6                   | 3.0                     |
| M-33% RC | 18                     | 22.8                   | 9.2                     |
| M-50% RC | 27                     | 23.7                   | 10.1                    |

According to the test data measured in this section, the reduction coefficient of the flexural strength $\phi_f$ and the reduction coefficient of the splitting tensile strength $\phi_s$ are obtained by fitting, as shown in equations (3) and (4) respectively.

$$\phi_f = 1 - 1.389\varphi_p - 1.637\varphi_r \quad (3)$$

$$R^2 = 0.968$$
\[
\phi_s = 1 - 1.839\phi_p - 1.728\phi_r \\
R^2 = 0.892
\]  

(4)

The comparison between fitting results and test results is shown in Figure 3.

![Image](image.png)

**Figure 3.** The comparison between fitting results and test results

As can be seen from the figure, the addition of rubber significantly reduces the compressive strength of cement mortar. Under the same rubber particle size, the compressive strength of rubber cement mortar decreases with the increase of rubber content. The compressive strength of cement-based materials with small particle size rubber is lower under the same rubber content. When the rubber content is 50%, the rubber particle size has little influence on the compressive strength of cement mortar.

4. Study on elastic modulus of rubber cement mortar

Elastic modulus is a measure reflecting the elastic deformation of material, an index of material stiffness, and an important parameter of cement-based material properties. The elastic modulus test method of rubber cement mortar shall refer to JGJ 70-90 basic Performance Test Method for Building Mortar.

Cement mortar is a kind of multiphase composite material. In order to simplify the microscopic mechanical analysis, cement mortar can be regarded as a two-phase composite material with dispersed fine aggregate embedded in the cement stone matrix, and its elastic modulus can be calculated. There are two common calculation models: parallel model and series model, as shown in Figure 4.

![Image](image.png)

**Figure 4.** The parallel model and series model
Assuming that the elastic modulus of the complex is $E$, that of the two materials is $E_1$ and $E_2$ respectively, and that of the two materials is $V_1$ and $V_2$ respectively, the elastic modulus of the parallel model is (5).

$$E = E_1V_1 + E_2V_2$$

The elastic modulus of the series is (6).

$$E = \frac{E_1E_2}{E_1V_2 + E_2V_j}$$

Will rubber cement mortar as introduced by rubber particle and its pore common Mosaic composed of three-phase composite material, in cement mortar will be introduced by rubber high porosity pore formation as rubber mortar layer and interface transition zone of cement mortar, the cement mortar as a two-phase composite material consisting of cement and sand, using binary complex elastic modulus calculation model, three calculation rubber elastic modulus of cement mortar.

Figure 5. The Schematic diagram of micro structure of rubber cement mortar

The calculated elastic modulus is applicable to rubber cement mortar with different grain size and different rubber content. Therefore, it can be considered that the elastic modulus prediction method proposed in this section can effectively predict the elastic modulus of rubber cement mortar.

5. Conclusions

This article uses three different particle size of rubber, rubber cement mortar as the research object, from microscopic, mesoscopic and macroscopic aspects, the rubber is studied through experimental research and theoretical analysis on the basic performance of cement mortar mixture, transition zone interface and pore structure, basic mechanical properties, the influence of drying shrinkage performance and cracking resistance. The main conclusions are as follows:

1. The influence of rubber on the fluidity of cement mortar mixture is mainly influenced by the size of rubber particle size. Large-size rubber can improve the fluidity of cement mortar, while small-size rubber can reduce the fluidity of cement mortar, that is, the fluidity of rubber cement mortar decreases with the decrease of rubber particle size;

2. The fractal dimension $D$ of rubber cement mortar decreases with the increase of rubber content and the decrease of particle size;

3. Additional pores introduced by rubber into mortar have an impact on mechanical properties, drying shrinkage and cracking resistance of cement mortar. Porosity itself has an effect on other durability of cement-based materials.
Therefore, this paper deduces the elastic modulus prediction formula of rubber cement mortar and explains the reason why the difference of rubber particle size affects the mechanical properties of cement mortar.

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