The Present Research Focuses on the Effects of Rubber Particle Size on Mortar Performance Characteristics

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Abstract: Crushing scrap tires as an aggregate to be mixed into concrete for the production of elastic concrete is an environmentally friendly way to use scrap rubber in large quantities. There have been a large number of research results on the effect of waste rubber aggregate on concrete properties. In this paper, different particle size rubber aggregate is used to prepare mortar samples with less than 25% admixture, test the rubber mortar weight, fluidity, flexural strength, compressive strength and stress-strain with rubber admixture change rule, and investigate the effect of different particle size rubber on mortar workability and mechanical properties. Under the condition of the same particle size, with the increase of rubber aggregate doping, the mortar gas content increases, the weight capacity decreases, and the fluidity decreases; under the condition of the same doping, with the decrease of rubber aggregate particle size, the mortar gas content increases, the weight capacity decreases, and the fluidity decreases. Under the condition of the same particle size, with the increase of rubber aggregate doping, the mortar gas content increases, the capacity decreases, and the fluidity decreases; under the condition of the same doping, with the decrease of rubber aggregate particle size, the mortar gas content increases, the capacity decreases, and the fluidity decreases. Under the condition of the same particle size, with the increase of rubber aggregate doping, the mortar gas content increases, the capacity decreases, and the fluidity decreases; under the condition of the same doping, with the decrease of rubber aggregate particle size, the mortar capacity decreases, and the fluidity decreases. Under the condition of the same particle size, with the increase of the rubber aggregate dosage, the mortar capacity decreases and the fluidity decreases; under the condition of the same dosage, with the decrease of the rubber aggregate particle size, the mortar capacity decreases and the fluidity decreases.

Keywords: *Rubber Particle Size; Workability; Compressive Strength; Stress-Strain*

I. INTRODUCTION

The buildup of waste tires over time has also led to concerns regarding its non biodegradable nature. The absence of proper management of these waste tires has been demonstrated to pose significant health risks to humans. In addition to its potential to generate fire hazards, the accumulation of waste tires has been linked to the proliferation of disease-carrying mosquitoes, which can pose a serious threat to public health[1-3]. This phenomenon has been referred to as "black pollution," emphasizing the critical environmental and health concerns associated with this issue.

The workability of waste rubber concrete (such as workability, fluidity, and compactness) gradually decreases with the increase of rubber content, while its bulk density also significantly decreases[4-6]. The impact resistance, ductility, and toughness of waste rubber concrete significantly improve with the increase of rubber content, while its strength gradually decreases as the rubber content increases[7-9]. This study investigates the fresh-state and mechanical properties of rubberized mortar by incorporating rubber aggregates of varying particle sizes and analyzing their performance variations with different dosage levels.

II. EXPERIMENTAL PROCEDURES

A. Raw materials and mixing ratios

The rubber particles used in this experiment were 5mesh (average particle size of 2 mm), 40mesh (average particle size of 0.425 mm), and 100mesh (average particle size of 0.15 mm) rubber aggregates produced by crushing waste tires at a factory. The apparent density of the rubber particles was 1042 kg/m³. The cement was sourced from Qianye Cement Co., Ltd., Jiaozuo City, Henan Province. The fine aggregate consisted of natural river sand, and its performance parameters are listed in Table 1. A high-efficiency naphthalene-based superplasticizer was employed as the water-reducing admixture.

Table 1: Performance parameters of river sand

Quality indicators	Apparent densitykg/m³	void ratio	Fineness modulus
Test value	2850	30.42	2.97

Table 1: Mixing ratio

NO.	Water/g	Sand/g	Cement/g	Rubber /g	Water reducing agent /g
CR0	249.5	1362	454	0	4.54
CR5-5	249.5	1293.9	454	24.06	4.54
CR5-10	249.5	1225.8	454	48.12	4.54
CR5-15	249.5	1157.7	454	72.19	4.54
CR5-20	249.5	1089.6	454	96.25	4.54
CR5-25	249.5	1021.5	454	120.31	4.54
CR40-5	249.5	1293.9	454	24.06	4.54
CR40-10	249.5	1225.8	454	48.12	4.54
CR40-15	249.5	1157.7	454	72.19	4.54
CR40-20	249.5	1089.6	454	96.25	4.54
CR40-25	249.5	1021.5	454	120.31	4.54
CR100-5	249.5	1293.9	454	24.06	4.54
CR100-10	249.5	1225.8	454	48.12	4.54
CR100-	249.5	1157.7	454	72.19	4.54

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CR100-20	249.5	1089.6	454	96.25	4.54
CR100-25	249.5	1021.5	454	120.31	4.54

B. Experimental test methods

2.2.1 Capacity weight

The fresh mortar capacity weight test is conducted in accordance with the provisions outlined in GB/T 50080-2016, which stipulates the performance standards for ordinary concrete mixes.The weighing cylinder employed in this test has a capacity of 1 L. Prior to the test, it is imperative that the inner and outer walls of the cylinder be thoroughly wiped clean to ensure accurate measurement of the test specimen's mass, denoted as G1, with a precision of 10 g.Following the mixing of the fresh mortar, it is loaded into the pounding and vibration apparatus. The excess mortar mixture is then scraped away from the mouth of the cylinder, any depressions on the surface are filled in, and the outer wall of the cylinder is wiped clean. The total mass of the mortar mixture and the cylinder G2 is then weighed, with an accuracy of 10 g.The apparent density of the mortar mixture is calculated as G2 minus G1.

2.2.2 Fluidity

The standard reference method for testing the fluidity of fresh mortar is outlined in GB/T 2419-2005, entitled "Cementitious Sand Flow Determination Method." Prior to commencing the preparation of the freshly mixed mortar, it is essential to moisten the surface of the jumping table, the inner wall of the test mold, the pounding rod, and the utensils that will come into contact with the freshly mixed mortar. The freshly mixed rubber mortar was expeditiously loaded into the flow test mold in two layers, vibrated using the tamping rod, scraped off the rubber sand above the mold, and wiped off the rubber sand that fell on the jumping table.Then, the truncated cone mold was lifted vertically upwards.The jump table was immediately turned on, within 30 ± ls, to complete 25 jumps. Subsequent to the completion of the jump, a ruler was employed to measure the maximum diffusion diameter of the fresh mortar and its perpendicular diameter. The average value was then calculated and expressed in millimeters.

2.2.3 Compressive strength

The compressive strength test method of rubber mortar was also referred to the Standard for Test Methods of Physical and Mechanical Properties of Concrete (GB/T 50081-2019), and a microcomputer-controlled flexural and compressive testing machine (YAW-300C, Jinan Liangong Testing Technology Co., Ltd., China) was used. The machine's loading speed was set at 2.4 kN/s during the test.

2.2.4 Flexural strength

The flexural strength test method of rubberized mortar was referred to the Standard for Test Methods of Physical and Mechanical Properties of Concrete (GB/T 50081-2019), and a microcomputer-controlled flexural and compressive testing machine (YAW-300C, Jinan Liangong Testing Technology Co., Ltd., China) was used. During the test, the loading speed of the aforementioned machine was set at 50 N/s, and the loading was continued until the specimen broke.

2.2.5 Stress-strain

The rubberized mortar was subjected to axial compression testing using an electronic universal testing machine (WDW-300 KN, Shanghai Bairuo Testing Instrument Co., Ltd., China). During the test, the loading rate was maintained at 0.20 mm/s, and the load-displacement curve was recorded. The stress-strain curve was subsequently calculated from the recorded data. Prior to the initiation of the test, the position of the upper platen must be adjusted to ensure that it is in direct contact with the upper surface of the specimen, thereby ensuring a uniform force application.

III. RESULT AND DISCUSSION

A. Capacity weight

As illustrated in Figure 1, the weight capacity of rubber mortar is influenced by variations in particle size and dosage. The incorporation of diverse rubber particles into the fresh mortar results in a decline in apparent density relative to the blank group. However, the impact of particle size on mortar capacity varies. For a constant amount of mixing, the capacity of rubber mortar is greater for 5 mesh rubber particles compared to 40 mesh and 100 mesh particles. When mixed with 5 mesh rubber particles, the mortar capacity weight relative to the blank group exhibited a reduction of 8.34%, 11.75%, 12.29%, 15.59%, and 17.04%, respectively. Similarly, when mixed with 40 mesh rubber particles, the mortar capacity weight relative to the blank group showed a reduction of the mortar capacity weight relative to the blank group was reduced by 12.84%, 16.93%, 22.15%, 24.32%, and 27.64%, respectively, when mixed with 100 mesh rubber particles. 5%, 24.32%, 27.64%, respectively. The mortar capacity weight was reduced by 14.01%, 19.43%, 22.72%, 25.40%, 27.77%, respectively, relative to the blank group. The experimental findings demonstrate a direct correlation between the decrease in mortar capacity and the increase in rubber dosing, while concurrently indicating an increase in capacity with a decrease in rubber particle size.It is noteworthy that when equal volumes of rubber and sand are incorporated into the mortar, the rubber replaces the sand. However, the density of rubber is considerably lower than that of sand, and a high dosage of rubber can result in a reduction in capacity[10].

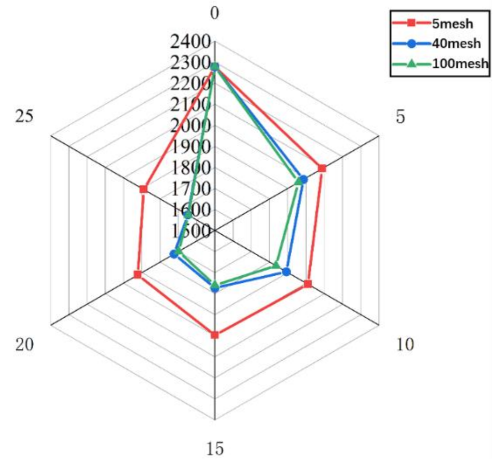

Fig. 1Rubber mortar capacity for different particle sizes and dosages

B. Fluidity

Fig.2 illustrates the flowability of rubberized mortar with varying particle sizes and dosages.The results demonstrate that the effects of different particle sizes of rubber particles on the fluidity of fresh mortar are also different.As the proportion of 5-mesh rubber particles increases, the flowability of mortar gradually increases. Conversely, the incorporation of 5mesh rubber particles led to a decline in mortar fluidity by 4.40%, 14.58%, 16.44%, 20.14%, and 21.99%, respectively, compared to the blank group. The study also revealed that the increase in rubber admixture resulted in a gradual decrease in mortar fluidity. The addition of 5mesh rubber particles, however, exhibited an enhancement in the fluidity of the mortar. The addition of 40mesh rubber particles resulted in a 2.78%, 2.78%, 6.94%, 9.72%, and 9.72% decrease in mortar fluidity, respectively, relative to the blank group. Similarly, an increase in the amount of rubber mixed resulted in a gradual decrease in fluidity. In the case of 100 mesh rubber particles, the flowability of mortar decreased by 7.41%, 12.96%, 24.07%, 34.72%, and 40.28%, respectively, relative to the blank group. In summary, with the same admixture, fluidity of 5 mesh > 40 mesh > 100 mesh, the fluidity of the mortar exhibited a tendency to decrease with the decrease of particle size. In instances where a substantial disparity exists between the aggregate particle sizes, the discrepancy in size between the rubber particles and the aggregate gives rise to considerable friction, thereby impeding the fluidity of the mortar.[11,12]

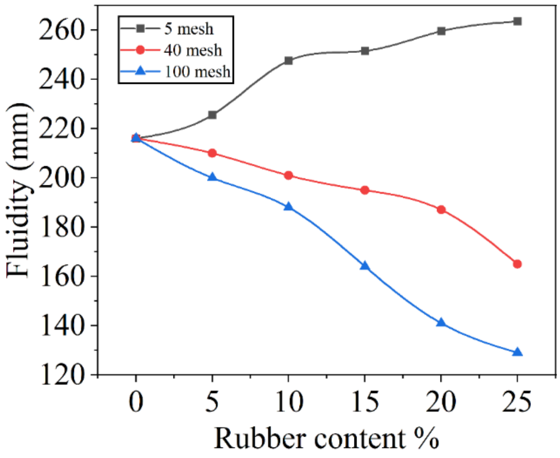

Fig. 2 Fluidity of rubber mortar with different particle size and dosage

C. Compressive strength

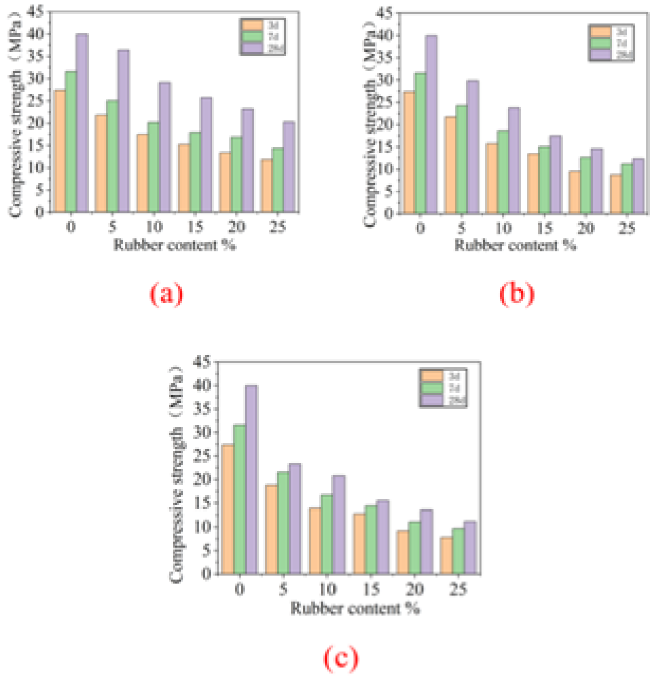

Fig. 3: Compressive strength of rubber mortar with different particle sizes and dosages

Fig.3 shows the compressive strength of mortar with rubber particles and particle size change curve; the same particle size conditions, with the increase of rubber particles, the compressive strength of mortar first rapid decrease and then slow down the rate of reduction; the same dosage conditions, with the rubber particle size decreases, the compressive strength of mortar continues to decrease, in the high dosage, the strength of the change with the particle size is no longer significant. Mixed with 5 mesh rubber particles, the 28 d compressive strength of mortar relative to the blank group decreased by 12.50%, 20.42%, 26.81%, 30.97%, 37.50%; mixed with 40 mesh rubber particles, the 28 d compressive strength of mortar relative to the blank group decreased by 15.28%, 29.17%, 32.36%, 42.36%, 46.81%; The 28 d compressive strength of mortar was reduced by 23.61%, 34.03%, 42.64%, 45.69%, 49.72% for 100 mesh rubber particles, respectively, compared with the blank group.

D. Flexural strength

As illustrated in Fig.4, the flexural strength of mortars with rubber particles and varying particle sizes exhibits a similar trend to the compressive strength. In the context of constant particle size, the incorporation of rubber particles initially leads to a rapid decline in mortar flexural strength, followed by a gradual deceleration in the rate of reduction. The overall reduction rate in this scenario is less pronounced compared to the changes observed in the compressive strength of rubber mortars.Conversely, when the reduction in rubber particle size is taken into account, the mortar flexural strength undergoes a decline, and the impact of particle size becomes less significant under high levels of doping. When 5 mesh rubber particles were incorporated, the 28 d flexural strength of mortar exhibited a decrease of 8.95%, 27.21%, 35.72%, 41.97%, and 49.22%, respectively, compared with the blank group. Similarly, when 40 mesh rubber particles were incorporated, the 28 d flexural strength of mortar diminished by 25.46%, 40.57%, 56.48%, 63.48%, and 69.23%, respectively, compared with the blank group. A similar trend was observed for 100 mesh rubber particles, with a 41.72%, 47.97%, 61.18%, 65.98%, and 71.98% reduction in 28 d flexural strength compared to the blank group.

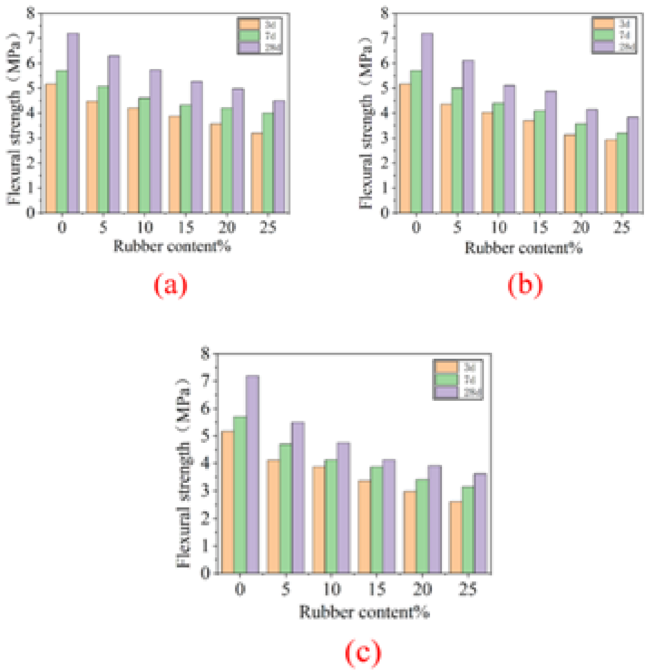

Fig. 4 Flexural strength of rubber mortar with different particle sizes and dosages

The incorporation of rubber particles into mortar leads to a reduction in flexural and compressive strengths, a phenomenon attributable to the inherent characteristics of rubber particles and the deleterious effect of rubber on mortar strength[13-15]. Firstly, rubber, being an elastic material, possesses a lower stiffness compared to sand, resulting in inadequate resistance to sufficient loads [16]. Secondly, the hydrophobicity of rubber leads to weak adhesion between rubber and cementitious materials, resulting in larger cracks in the interface transition zone under external forces [17].

E. Stress-strain

As illustrated in Fig.5, the stress-strain curves of rubber mortar with varying rubber particle doping and particle size demonstrate a decline in peak strength with increasing rubber doping. The modulus of elasticity E of the rubber mortar also exhibits a gradual decrease, accompanied by an increase in toughness. Notably, at a constant dosage, the modulus of elasticity of smaller particle size is lower than that of rubber mortar with larger particle size. The incorporation of rubber particles enhances the crack resistance and ductility of the mortar, and the elastic modulus of the mortar displays a gradual decrease as the rubber particle size decreases.

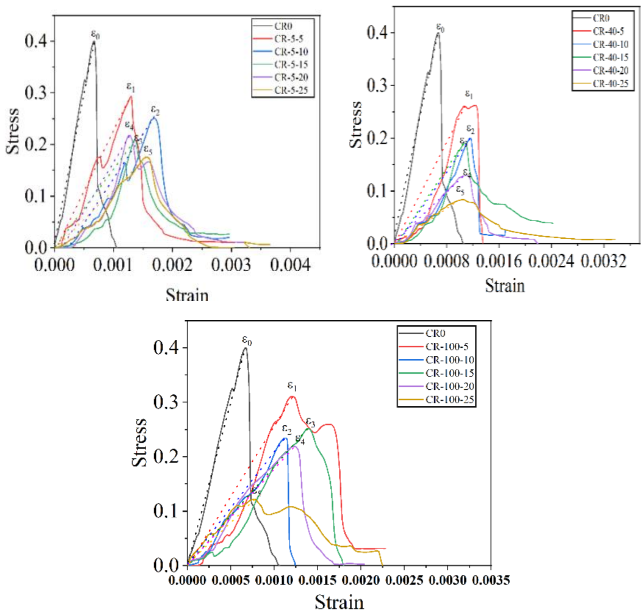

Fig. 5 Stress-strain curves of rubber mortar with different particle sizes and dosages

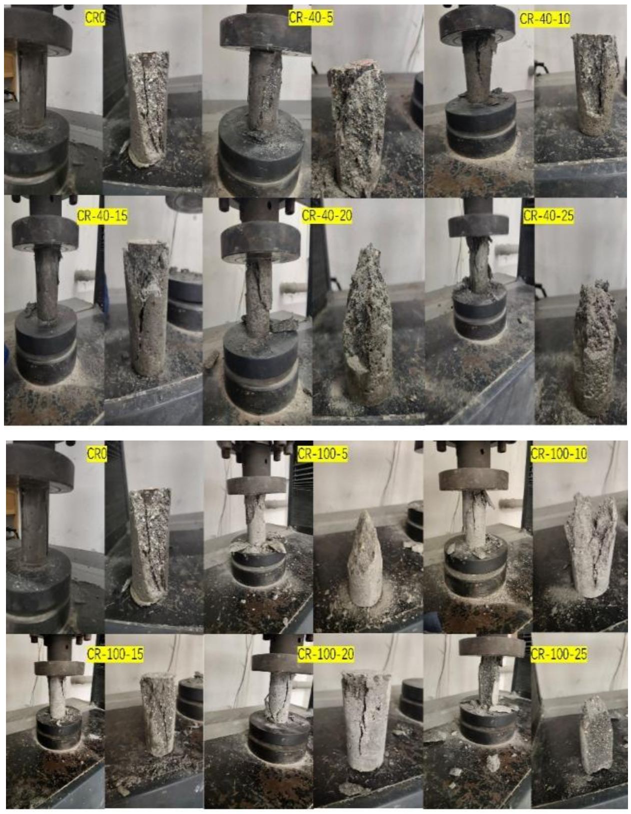

Fig. 6 Damage patterns of rubber mortars with different particle sizes and dosages under compression

As illustrated in Fig.6, CR0 displays a distinct pattern of brittle damage at the moment of destruction. With increasing rubber doping, the damage pattern of the mortar begins to exhibit signs of toughness. Under the same rubber admixture, the ductile morphology of smaller particle size rubber mortar is more pronounced. This is attributable to the fact that smaller rubber particles can be distributed more uniformly within the concrete, thereby ensuring more uniform stress dispersion during crack damage, resulting in enhanced ductility.

CONCLUSION

In the context of constant particle size, an increase in rubber aggregate dosage results in a decrease in mortar weight and fluidity. Conversely, a decrease in rubber aggregate particle size leads to a reduction in mortar weight and fluidity. Furthermore, an increase in rubber aggregate dosage results in a decrease in compressive flexural strength of mortar, while a decrease in rubber aggregate particles leads to a similar decrease. The addition of rubber has been shown to enhance crack resistance and ductility in mortars, and the elastic modulus of mortars exhibits a gradual decrease as the size of rubber particles decreases.

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