Journal of Materials Science and Chemical Engineering, 2019, 7, 18-23
http://www.scirp.org/journal/msce
ISSN Online: 2327-6053
ISSN Print: 2327-6045

# Study on Modification of Waste Rubber Powder in Cement-Based Composites Mixed with Waste Rubber Powder

**Jianmei Zhou**

School of Chemistry and Chemical Engineering, Inner Mongolia University of Science & Technology, Baotou, China
Email: zjmwjy@aliyun.com

**How to cite this paper:** Zhou, J.M. (2019) Study on Modification of Waste Rubber Powder in Cement-Based Composites Mixed with Waste Rubber Powder. *Journal of Materials Science and Chemical Engineering*, **7**, 18-23.
https://doi.org/10.4236/msce.2019.78003

**Received:** July 20, 2019
**Accepted:** August 9, 2019
**Published:** August 12, 2019

## Abstract

In view of the disadvantage that the mechanical properties of cement-based composites can be significantly reduced by incorporating waste rubber powder *in situ*, the surface modification methods of the original rubber powder by coupling agent KH560, sodium hydroxide, polyvinyl alcohol (PVA), methyl hydroxyethyl cellulose ether (MHEC) and tetraethyl orthosilicate (TEOS) as precursors were adopted respectively. The modification of waste rubber powder was studied by Change rate of mortar strength of cement-based composite mortar mixed with waste rubber powder. The results show that the hybrid modification method using tetraethyl orthosilicate as precursor has better effect. When 5 phr ethyl orthosilicate is added, the compressive strength and flexural strength of cement-based composite mortar can be increased by 31.7% and 28%. Scanning electron microscopy (SEM) results show that the surface of waste rubber powder with good modification effect has many protrusions and flake-like porous structures which are beneficial to its bonding with cement-based materials.

## Keywords

Waste Rubber Powder, Modification, Mechanical Properties, Cement-Based Composites

## 1. Introduction

At present, waste rubber is a kind of polymer pollutant next to plastic pollution [1]. How to improve the recycling of waste rubber is an urgent problem to be solved all over the world. When waste rubber powder is added into cement-based materials, the sound absorption and thermal insulation of the composites will be enhanced [2], but the mechanical properties of cement-based composites will be significantly reduced [3]. Therefore, proper modification of rubber powder is the key to improve its application value in cement-based materials.

The modification methods of waste rubber powder can be roughly divided into regeneration desulfurization method, mechanochemical method, polymer coating method, physical radiation and gas modification method and hybrid modification method [4] [5] [6]. There are some problems in practical application, such as complex process and high cost. In the relevant literature, the modification method of waste rubber powder used in cement concrete is less, which is limited to sodium hydroxide treatment, coupling agent treatment and so on. In this paper, the surface modification of waste rubber powder was carried out with coupling agent KH560, sodium hydroxide, polyvinyl alcohol PVA, methyl hydroxyethyl cellulose ether (MHEC) and hybrid modification method using tetraethyl orthosilicate (TEOS) as precursor [6]. The effect of modified rubber powder on the mechanical properties of cement mortar was studied, and various methods were analyzed. The modification effect provides basic research for the industrial application of waste rubber powder in cement-based materials.

## 2. Experimental Materials

Waste rubber powder (40 mesh, 60 mesh) is purchased from Zhidaxin Rubber Products Co., Ltd. of Baotou City, Inner Mongolia; cement is P.O42.5 grade of Inner Mongolia Mengxi Cement Co., Ltd.; standard sand is ISO standard sand of China Xiamen Eseo Standard Sand Co., Ltd.; other reagents are analytical pure.

## 3. Methods

**NaOH Modified Rubber Powder:** Waste rubber powder was immersed in NaOH saturated solution for 24 hours, removed and dried, and then dried naturally.

**PVA Modified Rubber Powder:** Waste rubber powder was immersed in 1.5% PVA solution for 24 hours, removed and dried, and then dried naturally.

**KH560 Modified Rubber Powder:** A suitable amount of KH560 was dissolved in a small amount of 95% ethanol as solvent and then added to the waste rubber powder. The rubber powder was put into the ceramic grinding for 1 hour to make it fully contact and react.

**MHEC Modified Rubber Powder:** Mixed with 0.20% MHEC and waste rubber powder for grinding.

**TEOS Hybrid Modified Rubber Powder as Precursor:** It was prepared by referring to the method in reference [5].

According to GB/T 17671-1999, the mechanical properties of cement-based composite mortar with rubber powder were tested. The amount of waste rubber powder was 9% of the cement quality.

S-3400N scanning electron microscopy of Hitachi Company in Japan was used to observe the micro-morphology of waste rubber powder before and after modification.

## 4. Results and Discussion

**Contrastive Analysis of Strength and Strength Change Rate. Table 1** shows the effect of waste rubber powder modified by different methods on the strength of cement matrix composite mortar. **Figure 1** and **Figure 2** show the change rate of mortar strength of waste rubber powder cement-based composites modified by different methods. From **Table 1**, **Figure 1** and **Figure 2**, it can be seen that the use of KH560, NaOH and TEOS to modify waste rubber powder can improve the strength of cement-based composites. The hybrid modification of TEOS is due to the interpenetrating Si-O network structure formed by the reaction precursor and vulcanization network of rubber powder, and forms on the surface of rubber powder. A large number of hydrophilic groups had the best modification effect. The 28-day flexural strength and compressive strength were increased by 28.3% and 31.7%, respectively. However, after the modification of waste rubber powder by PVA and MHEC, the mortar strength of cement-based composites is reduced, and the effect is not good.

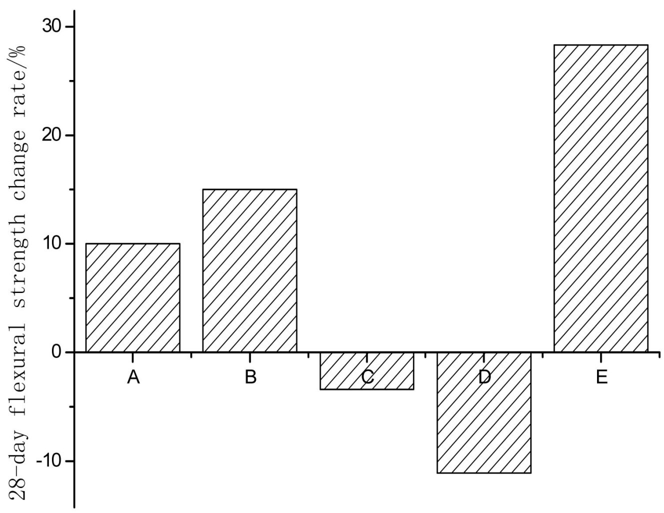


**Figure 1.** Change rate of 28 d flexural strength. Note: In **Figure 1** and **Figure 2**. A: KH560 modified; B: NaOH modified; C: PVA modified; D: MHEC modified; E: TEOS Hybrid modified.

**Table 1.** Mortar strength of cement-based composites mixed with waste rubber powder.

| Waste rubber powder | Unmodified | KH560 modified | NaOH modified | PVA modified | MHEC modified | TEOS Hybrid modified |
|---|---|---|---|---|---|---|
| 28 d flexural strength/MPa | 6.00 | 6.60 | 6.90 | 5.79 | 5.33 | 7.70 |
| 28 d compressive strength/MPa | 33.10 | 37.01 | 34.59 | 31.74 | 22.57 | 43.59 |

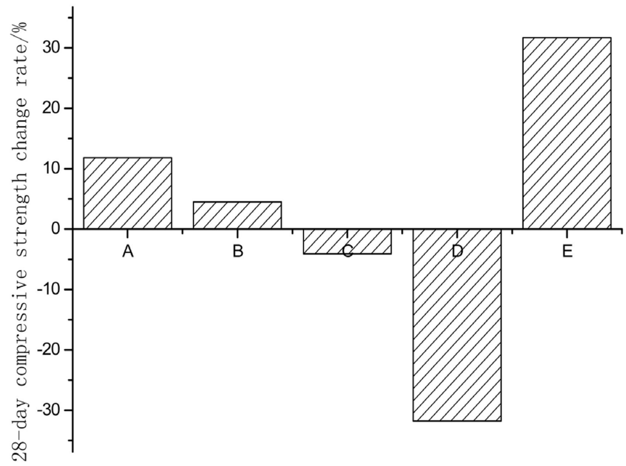


**Figure 2.** Change rate of 28 d compressive strength. Note: In **Figure 1** and **Figure 2**. A: KH560 modified; B: NaOH modified; C: PVA modified; D: MHEC modified; E: TEOS Hybrid modified.

**SEM Analysis. Figure 3** shows the SEM spectra of waste rubber powder with different modification methods. It can be seen that different modification methods have different effects on the morphology of waste rubber powder. The surface of waste rubber powder hybrid modified by coupling agent KH560, NaOH and TEOS has more protrusions, and the waste rubber powder hybrid modified by TEOS is close to the flake pore shape, which is more conducive to the combination of cement-based materials, hydration products and rubber particles, so it shows better modification effect.

**Effect of the Mesh of Waste Rubber Powder. Table 2** shows the effect of the mesh of NaOH modified rubber powder on the strength of cement-based composite mortar. From **Table 2**, it can be seen that the compressive strength and flexural strength of cement mortar increased by 4.5% and 15% after adding 60 mesh NaOH modified waste rubber powder into cement mortar, while the compressive strength of cement mortar decreased by 9.9% and flexural strength increased by 3.2% when adding 40 mesh NaOH modified waste rubber powder. Therefore, from the point of view of replacing cement with waste rubber powder, 60 meshes should be considered.

## 5. Conclusions

The modification of waste rubber powder in cement-based composites mixed with waste rubber powder was analyzed and studied. It was found that KH560, NaOH and TEOS were used to modify waste rubber powder, which had good effect in cement-based composites. Among them, TEOS hybrid modification had the best effect. The 28-day flexural strength and compressive strength of cement-based materials were increased by 28.3% and 31.7% respectively. The mesh of waste rubber powder also has a certain influence on the properties of cement-based composites. From the point of view of replacing cement with waste rubber powder, 60 mesh of waste rubber powder is suitable.

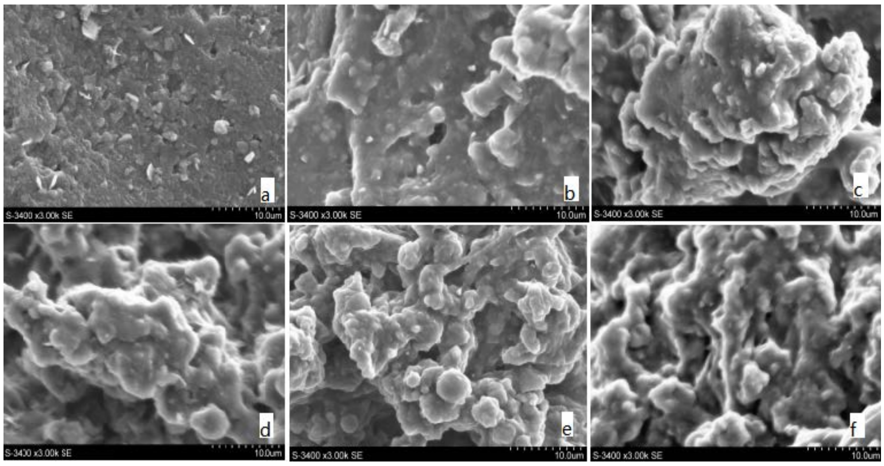


**Figure 3.** SEM Scrap of rubber powder. (a) Unmodified; (b) MHEC modified; (c) PVA modified; (d) NaOH modified; (e) KH560 modified; (f) TEOS hybrid modified.

**Table 2.** Effect of the mesh of waste rubber powder on the strength of cement matrix composite.

| Waste rubber powder | 40 Mesh | | 60 Mesh | |
|---|---|---|---|---|
| | Unmodified | NaOH modified | Unmodified | NaOH modified |
| 28 d flexural strength/MPa | 6.3 | 6.5 | 6 | 6.9 |
| 28 d compressive strength/MPa | 35.6 | 32.4 | 33.1 | 34.6 |

Scanning results of modified waste rubber powder showed that when the structure of modified waste rubber powder was bulging and tended to flaky porous structure, it was beneficial to its combination with cement-based materials and hydration products, and further explained the reason why hybrid modified rubber powder had good modification effect.

## Acknowledgements

Author wishes to thank Inner Mongolia Natural Science Foundation for funding through the project 2017MS (LH) 0514.

## Conflicts of Interest

The author declares no conflicts of interest regarding the publication of this paper.

## References

[1] Cao, Q. (2017) *Chinese Rubber*, **33**, 21-25. https://doi.org/10.4467/20843852.OM.17.002.9599

[2] Manning (2002) Content for Reclaim of Rubber Wasting in Europe. Plastic, Rubber Processing and Application.

[3] Chen, J. (2013) Experimental Study on Modification and Thermal Preservation of Rubber Mortar. Zhejiang University of Technology.

[4] Zheng, X. (2008) Surface Modification of Rubber Powder. China Building Materials Industry Publishing House.

[5] Yu, G., Liu, L. and Yu, Q. (2010) *Concrete*, **5**, 99-102. https://doi.org/10.4028/www.scientific.net/AMR.102-104.539

[6] Wang, Y., Liu, L., Fu, W., *et al*. (2006) *Progress in Chemical Industry*, **25**, 820-824.