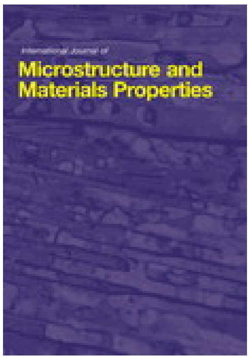

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The influence of carboxylated styrene butadiene lotion content on the microstructure of modified concrete

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Abstract: In order to study the influence of carbobutadiene latex on the properties of concrete, this study studied the influence of carbobutadiene latex content on the microstructure of modified concrete. First of all, material selection and production of specimens, and then the physical properties, mechanical properties and microstructure of specimens were analysed to complete the effect of carboxybutene styrene latex content on the microstructure of modified concrete. The experimental results show that the modified concrete has better performance, minimum water reduction rate and higher bulk density when the content of carboxybutene styrene emulsion is 15%. By observing the microstructure, it is found that there are tree-trunk structure, latex film structure and interpenetrating network structure between latex film and concrete hydration products. At the same time, there are conical particles, which can greatly improve the performance of concrete.

Keywords: carboxybutylbenzene; lotion content; modified concrete; microstructure.

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1 Introduction

In recent years, modern technology has been continuously applied in construction projects to improve construction quality. For building materials, the application of various new materials has improved their performance. For concrete, its durability is important, and adding high-efficiency water reducing agents during its manufacturing process can improve its performance. However, the addition of water reducing agents may also affect the hydration process of cement and affect its durability (Zhou and Dai, 2023; Deng et al., 2022). Therefore, there is a need to develop efficient water reducing agents and improve the working performance of cement-based materials. At present, commonly used water reducing agents include polyacrylate, carbonate, etc. However, these water reducing agents have disadvantages such as high cost and poor effectiveness. Therefore, finding a low-cost and high-performance concrete admixture has become a focus of research. As an environmentally friendly additive, styrene butadiene lotion has been widely used by the people due to its simple manufacturing and manufacturing costs (Hao, 2022). However, Styrene, 1,3-butadiene polymer is difficult to disperse and disperse evenly, so it must be used together with other components when mixed into concrete, which has affected the application of styrene butadiene lotion in concrete to a certain extent. In order to improve the interface problem between Styrene, 1,3-butadiene polymer and concrete, domestic and foreign scholars have studied the interface performance between Styrene, 1,3-butadiene polymer and concrete. Numerous studies have shown that adding carboxylic butylene styrene latex to concrete can improve the flowability of cement mixtures; The strength, flexural strength and compressive strength of concrete materials increase with the increase of lotion content; after adding carboxylic butylene styrene latex, a new interfacial transition zone gradually forms between the cement slurry and cement mortar in the concrete mixture; more bonding occurs between mortar and aggregates in concrete (Liu, 2022a). In recent years, Chinese scholars have also carried out requirements in this field and achieved certain research results. Wang et al. (2022) studied the effect of the addition of Styrene, 1,3-butadiene polymer on the mechanical properties and pore structure of belite cement mortar under the synergistic effect of high-temperature steam curing and carbonisation. The research results showed that the addition of Styrene, 1,3-butadiene polymer increased the porosity and large pore ratio of belite cement, significantly reducing the mechanical properties of polymer cement mortar, The addition of its lotion to the concrete can improve the flexural compression ratio of mortar and improve its toughness. However, due to the carbonation effect, the compressive strength of cement mortar increases significantly more than the flexural strength, which reduces the flexural compression ratio after carbonation; Wang and Jian (2021) used renewable polypropylene fibre (RPF) and Styrene, 1,3-butadiene polymer (SBR) to jointly act on concrete. Under the condition of 5% hydrochloric acid immersion, the compressive, tensile, and flexural strength of the concrete were tested after 90 days, and its compressive, tensile, and flexural strength were measured under the condition of 5% hydrochloric acid immersion. The mass loss rate and strength were also tested after 90 days, revealing the relationship between RPF and Styrene, The synergistic effect of 1,3-butadiene polymer on the basic mechanical properties and durability of concrete. Liu (2022b) used experiments to analyse the modification effect and mechanism of styrene butadiene lotion on cement-based backfill. Through experiments, it was found that with the increase of styrene butadiene lotion concentration, the morphology of slurry structure transited from honeycomb to closely arranged layered structure, and a large number of hydrated calcium silicate and ettringite connected and polymerised aggregates to form a whole, thus promoting the improvement of strength performance; when the concentration of styrene butadiene lotion is too high, the content of ettringite generated by hydration reaction is significantly increased, and the content of hydrated calcium silicate is reduced, resulting in a decrease in workability and compressive strength. The above three methods all discussed the influence of the content of styrene butadiene lotion on the performance of cement and concrete, and lacked the analysis of the influence of the content of styrene butadiene lotion on the microstructure of concrete. In order to deeply understand the influence of the amount of lotion on the microstructure of concrete and fundamentally improve the performance of modified concrete, this study, based on the above research, carried out a study on the influence of the amount of carboxylated styrene butadiene lotion on the microstructure of modified concrete. It is hoped that this can improve the performance of modified concrete mixed with carboxylated styrene butadiene lotion, so that it can be better used in civil engineering and improve its construction quality.

2 Test methods

2.1 Materials and equipment

The cement used in this study is ordinary Portland cement, with a water cement mass ratio of 0.4. The non ionic carbon butadiene styrene latex is selected, and its properties are shown in Table 1.

Table 1 Performance parameters of carboxylic butadiene style latex

Appearance	*Solid content (by mass)/%*	*Viscosity/ (Pa•s)*	*pH value*	*Grain diameter/nm*	*Minimum film forming temperature/°C*
Milk white liquid	46-48	11	10–100	9–10	150

The proportion of modified concrete is shown in Table 2 (Zhao et al., 2022; Gao et al., 2022).

Table 2 Modified concrete proportions and properties

Code	*Ratio of material mass to cement mass/%*						*Apparent density/ ($g•cm^{-3}$)*	*24 h water absorption (by mass)/ %*
	Cement	*Sand*	*Water*	*CNTs*	*SBR*	*Water reducing agent*		
PCNT0	100	150	45	0.3	0	1.5	2.26	5.08
PCNT1	100	150	44	0.3	5	1.0	2.09	4.03
PCNT2	100	150	42	0.3	10	0.8	1.98	3.54
PCNT3	100	150	40	0.3	15	0.5	1.85	2.83
PCNT4	100	150	38	0.3	20	0	1.73	2.78

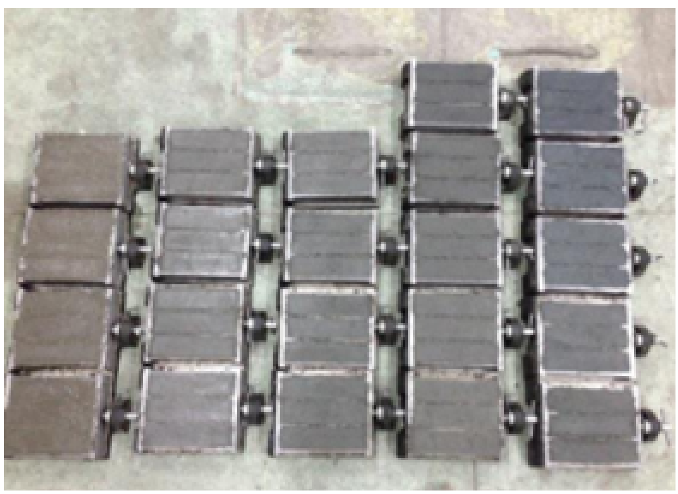
The selected equipment for this study is shown in Table 3.

Table 3 Experimental equipment

Device name	*Model*	*Manufacturer*
thermostat water bath	501	Shanghai Experimental Instrument Factory
Peristaltic pump	BT01-100	Bao'an Lange Constant Flow Pump Co., Ltd
Electric blender	D871	Zhengzhou Science and Trade Company
Water bath constant temperature oscillator	SHA	Beijing Medical Instrument Factory
HOCHECK	702-X	Dalian Drying Plant
Laser particle size analyser	90PLUS	BROOKHAVEN, USA
Universal testing machine	CMT5-5105	Shenzhen Xinsansi Material Testing Corporation

Based on Table 3 in conduct testing.

Figure 1 Physical image of specimen preparation (see online version for colours)



2.2 *Preparation of test pieces*

To simulate a real experimental environment, the testing process in this study was conducted at room temperature of 25°C, with an ambient humidity of 45%. Mix cement, sand, water reducer, and water according to the mix ratio in Table 2 using electric blender, and pre mix for three minutes. Quickly pre disperse carbon nanotubes on electric blender using SBR (or adding a certain amount of water) for ten minutes (Huang et al., 2022). Add the remaining water to the already mixed cement mortar, then turn on Mixmaster to mix SBR with CNTs, and slowly add SBR mixture to the mortar, stirring for two minutes. Then, add defoamer and quickly stir for three minutes to ensure uniform distribution of each component of the cement mortar (Liu et al., 2021; Tafadzwa et al., 2021). After the mixture is loaded into the trial mould, it is vibrated until no bubbles emerge, and then covered with plastic film. After 1 day, demolding can be achieved because the amount of cement used in the mix proportion is relatively large. If the traditional 'standard curing + dry curing' curing method is used, it will cause significant shrinkage and have a significant impact on the test results (Lei et al., 2023). Therefore, in this experiment, the curing temperature is set to 20°C and the humidity is set to 97%, maintain it in a standard manner. From this, concrete specimens were obtained, its size is 160 mm × 40 mm × 40 mm, as shown in Figure 1.

2.3 Test method

This study analysed and tested its physical properties, mechanical properties, and microstructure.

1 Physical performance: Water absorption rate test shall be completed according to German standard DIN52617, flowability test shall be completed according to GB/T2419-2017 document, and bulk density test shall be completed according to GB/T11970-2008 (Lei et al., 2022).

2 According to GB17671/1999 document standards, CMT5-5105 electronic universal testing machine produced by Shenzhen Xinsansi Materials Co., Ltd. was selected to measure the mechanical strength of modified concrete specimens with different carboxyl styrene butadiene lotion content (Yu et al., 2023).

3 Microstructure observation experiment. After conducting mechanical performance tests on the specimens, a smooth surface specimen was selected, and the specimens were hydrated with anhydrous alcohol. The specimens were dried and sprayed with gold powder for later observation of their microstructure using a laser particle size analyser.

3 Analysis of experimental results

3.1 Effect of carboxylic butadiene styrene latex content on the flow properties of modified concrete

The improved concrete flowability was tested and the results are shown in Table 4.

Table 4 Flow performance of modified concrete with different amounts of carboxylic butylene styrene latex

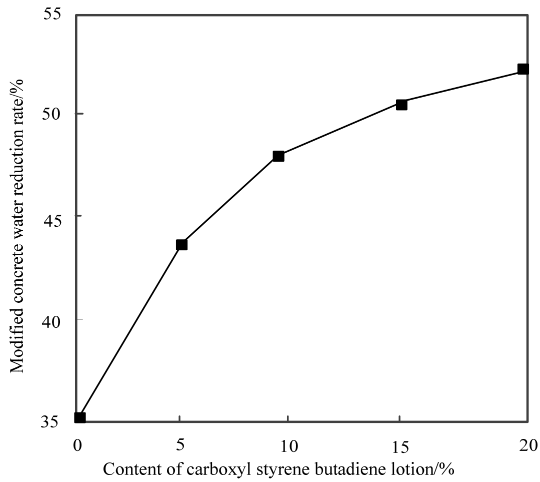
Code	*Flow (mm)*
PCNT0	176
PCNT1	174
PCNT2	172
PCNT3	173
PCNT4	172

As shown in Table 4, the flow rate of modified concrete is kept at 175 ± 5 mm. With the increase of the content of carboxylated styrene butadiene lotion, its flow performance gradually decreases. When its content reaches 20%, its flow rate is only 172 mm.

3.2 Effect of carboxylic butadiene styrene latex dosage on the water reduction rate of modified concrete

The influence curve of the dosage of carboxylic butadiene styrene latex on the water reduction rate of modified concrete is shown in Figure 2.

Figure 2 Changes in water reduction rate of modified concrete with different amounts of carboxylic butadiene styrene latex



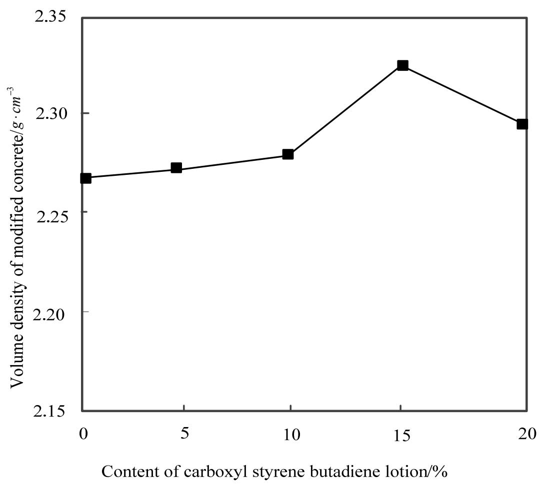
From Figure 2, it can be seen that with the increase of the content of carboxylic butylene styrene latex, the water reduction rate of modified concrete is enhanced. When the content of carboxylic butylene styrene latex reaches 15%, the growth rate slows down and the water reduction rate reaches about 50%. When the content of carboxylic butylene styrene latex is 20%, the water reduction rate is the highest, reaching 53.7%. From the figure, it can be seen that the addition of carboxylic butadiene styrene in concrete has good water reducing performance, which can improve its flow performance. Among them, the cement with a 20% content of carboxylic butadiene styrene latex has the best water reducing effect.

3.3 Effect of carboxylic butadiene-styrene latex dosage on the bulk density of modified concrete

When the fixed fluidity is 175 ± 5 mm for water curing, under different mixing ratios, the volume density of concrete increases with the addition of carboxylic butylene styrene latex, and the variation curve is shown in Figure 3.

It can be seen from Figure 2 that when the content of carboxylated styrene butadiene lotion is 0, its bulk density is only 2.261 g • cm^{-3}. With the increase of the content of carboxylated styrene butadiene lotion, the bulk density of the improved concrete shows a trend of first increasing and then decreasing. When the content of carboxylated styrene butadiene emulsion reaches 15%, its bulk density value is the highest, reaching 2.332 g • cm^{-3}. When the content of carboxylated styrene butadiene lotion is 20%, its bulk density value decreases, mainly due to the excessive water cement ratio. The change in bulk density of cement-based materials is mainly due to the presence of surfactants in the composition of carboxylic butylene styrene latex when it is added to cement mortar. The surfactants have an air entraining effect, which changes the internal pore structure of the mortar and changes its performance.

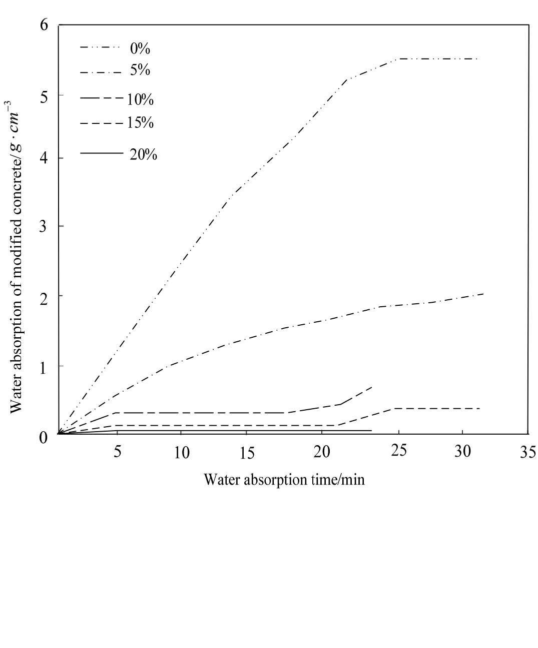
Figure 3 Changes in volume density of modified concrete with different carboxylic butadiene styrene latex content



3.4 Effect of carboxylic butadiene styrene latex dosage on the water absorption of modified concrete pores

The change curve of water absorption quality of modified concrete is shown in Figure 4 when the dosage of carboxylic butylene styrene latex is different.

Figure 4 Changes in water absorption of modified concrete with different amounts of carboxylic butylene styrene latex

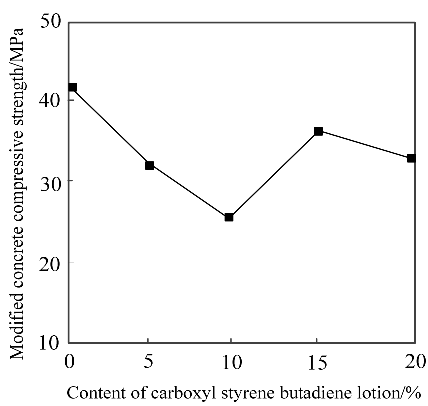


From Figure 4, it can be seen that when the dosage of carboxylic butylene styrene latex is the same, the longer the water absorption time, the better the water absorption quality of the modified concrete. However, in the later stage, the water absorption reaches equilibrium and the water absorption rate slows down. When the dosage of carboxylic butylene styrene latex increases, the water absorption decreases rapidly. When the dosage of carboxylic butylene styrene latex is 20%, the water absorption rate is only 0.288 kg/m^2. The main reason is that the modified concrete is affected by the consumption and evaporation of cement hydration reaction, and its water content gradually decreases, the distance between latex particles becomes closer, and gradually aggregates and forms a latex film. As the hydration reaction progresses, the lotion film and cement hydration products form a staggered, complex spatial network film structure on the interface, and play a role in plugging pores and cracks, making it have a significant water reduction effect.

3.5 The effect of carboxylic butadiene styrene latex content on the compressive strength of modified concrete

When the fixed fluidity is 175 ± 5 mm for water curing, the compressive strength changes of modified concrete with different amounts of carboxylic butylene styrene latex are shown in Figure 5.

Figure 5 Changes in compressive strength of modified concrete with different amounts of carboxylic butadiene styrene latex

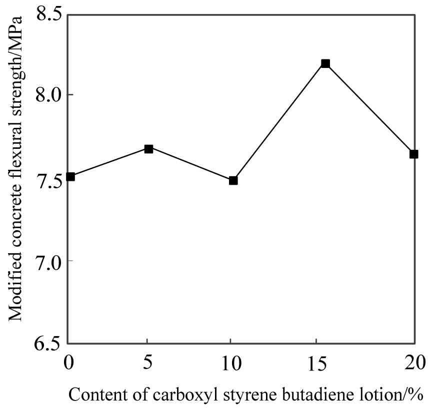


It can be seen from Figure 5 that with the increase of the content of carboxylated styrene butadiene lotion, the compressive strength of the modified concrete shows a trend of first increasing and then decreasing. When the content of its lotion is 15%, its compressive strength reaches the maximum, 37.5 MPa, while when the content of its lotion continues to increase to 20%, its compressive strength is reduced, only 31.2 MPa. Compared with conventional concrete, the compressive performance of modified concrete is lower, which is due to the low modulus of latex particles in the carboxylated styrene butadiene lotion. When pressed, it is like the holes in mortar. The experiment results in the reduction of the compressive strength of modified concrete, but the compressive strength loss of a small number of modified concrete is less.

3.6 The effect of carboxylic butadiene styrene latex content on the flexural strength of modified concrete

The changes in the flexural strength of modified cement mortar with different amounts of carboxylic butylene styrene latex under fixed fluidity of 175 ± 5 mm water curing are shown in Figure 6.

Figure 6 Changes in flexural strength of modified concrete with different amounts of carboxylic butadiene styrene latex



The change curve of the effect of the amount of carboxylic butylene styrene latex on the flexural strength of modified cement mortar under fixed fluidity of 175 ± 5 mm water curing. When the content of carboxylated styrene butadiene lotion is increased, the flexural strength of modified concrete decreases first, then increases and then decreases. When the content of carboxylated styrene butadiene lotion reaches 15.0%, the flexural strength is the highest, which is 8.25 MPa. When the content of carboxylated styrene butadiene lotion reaches 20.0%, the flexural strength decreases, which is only 7.61 MPa. This is mainly due to the higher flexural strength of some samples of modified concrete compared to pure cement mortar, which may be attributed to the increase in water cement ratio caused by high fluidity, leading to an increase in pores in the modified concrete and ultimately a decrease in flexural strength.

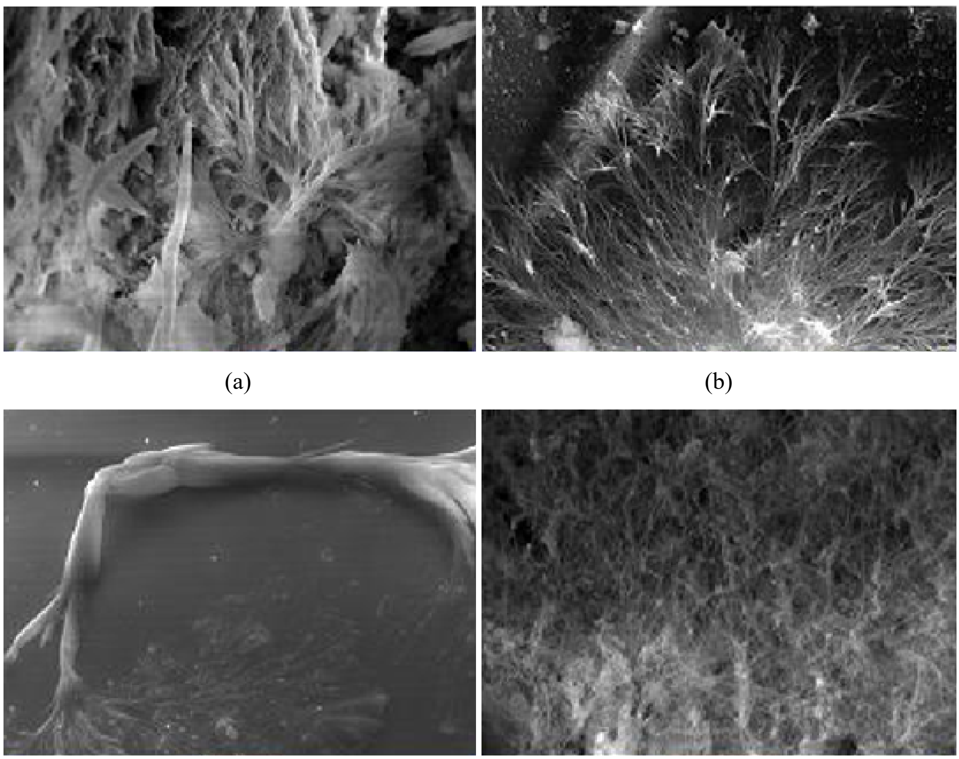
3.7 Effect of dosage on the microstructure of modified concrete

3.7.1 Microscopic study of modified concrete

The dendritic structure in modified cement mortar is shown in Figure 7.

As shown in Figure 7, when the content of carboxylic butylene styrene latex is small, the amount of dendritic structure is also small and relatively loose. When the content of carboxylic butylene styrene latex is 10%, its morphology is shown in Figure 7(a), with fewer dendritic structures; when the content of carboxylic butylene styrene latex is 10%, its morphology can be seen from Figure 7(b), where the branch structure becomes dense and a thin film has been formed at the bottom of the branch; when the dosage of carboxylic butylene styrene latex is further increased to 15%, it can be seen from Figure 7(c) that the dendritic structure is more lush, forming a thick trunk and a thin film at the slightly lower part of the branch; when the content of carboxylic butylene styrene latex increases to 20%, it can be seen from Figure 7(d) that the dendritic structure has formed a network structure. The dendritic structure can greatly enhance the toughness of materials and improve their flexural strength. From this, it can be concluded that when the dosage of carboxylic butylene styrene latex is 15%, its application performance is better.

Figure 7 Dendritic structure in modified cement mortar, (a) carboxybutylbenzene content is 5% (b) carboxybutylbenzene content is 10% (c) carboxybutylbenzene content is 10% (d) carboxybutylbenzene content is 20%



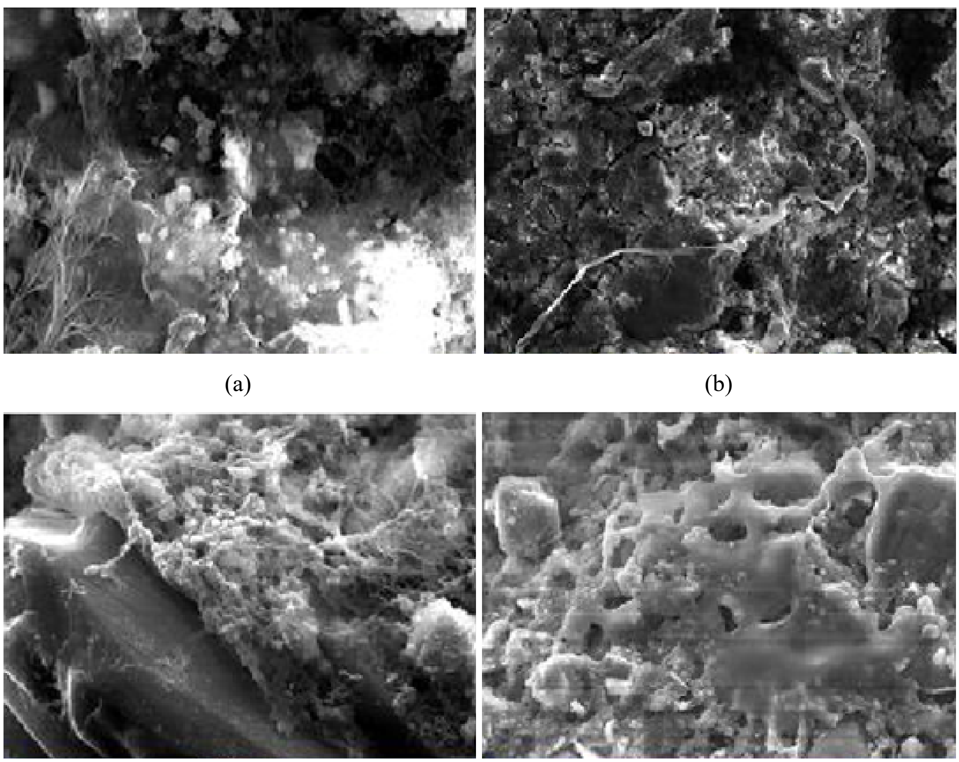
(a) (b) (c) (d)

3.7.2 Different forms of latex films

The tightly packed latex particles in improved concrete can form a latex film under certain conditions, and the morphology and structure of the latex film in modified cement mortar are shown in Figure 8.

From Figure 8(a), it can be seen that when the content of carboxylic butadiene styrene latex is 5%, the latex film in concrete will undergo certain deformation, causing cracks in its structure to be closed, thereby improving the impermeability and toughness of the modified concrete material; from Figure 8(b), it can be seen that when the content of carboxylic butadiene styrene latex is 10%, the latex film exhibits a network structure and warps at the interface, firmly connecting the cement hydrate with the aggregate, thereby further enhancing its performance; from Figure 8(c), it can be seen that when the content of carboxylic butadiene styrene latex is 15%, the latex film forms an interpenetrating network structure due to the expansion and rupture of hydration products; from Figure 8(d), it can be seen that when the content of carboxylic butadiene styrene latex is 20%, the fully developed interpenetrating latex film becomes more dense and the surface is extremely smooth. The interpenetrating network structure formed by the latex film and cement hydration products is extremely significant. From this, it can be concluded that the more the content of carboxylic butadiene-styrene latex is added, the more significant its impermeability and toughness are. Therefore, when the content of carboxylic butadiene-styrene latex reaches 20%, its impermeability is stronger.

Figure 8 Morphological structure of modified concrete latex film, (a) carboxybutylbenzene content is 5% (b) carboxybutylbenzene content is 10% (c) carboxybutylbenzene content is 10% (d) carboxybutylbenzene content is 20%



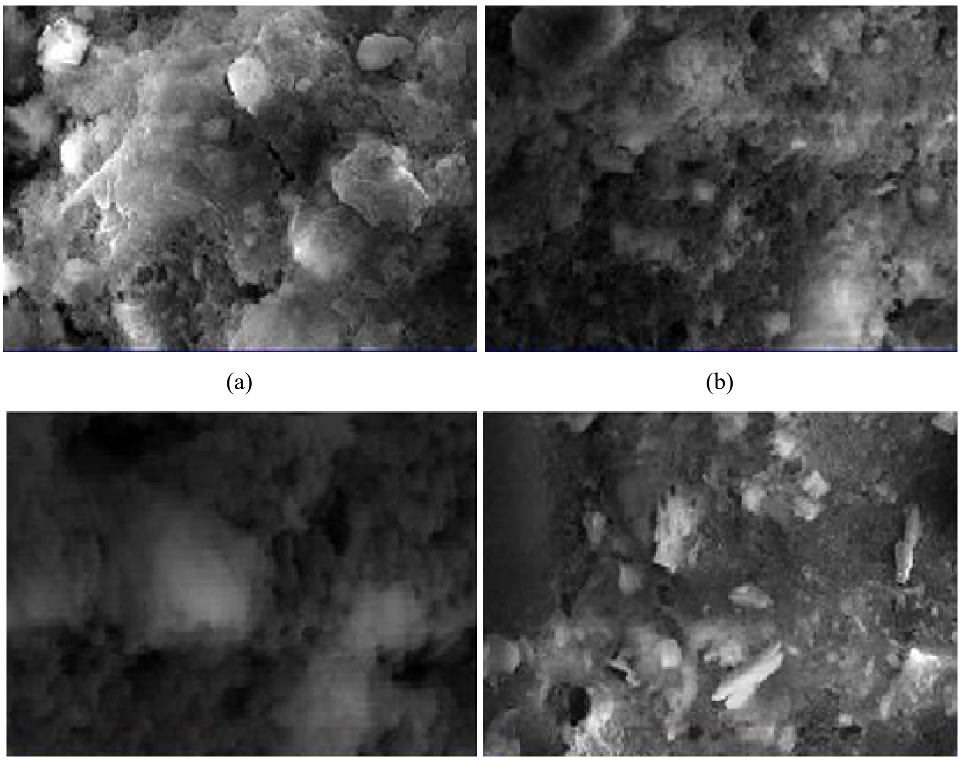
(a) (b) (c) (d)

3.7.3 Morphological structure of modified concrete latex particles

The morphology and structure of latex particles in modified cement mortar are shown in Figure 9.

As shown in Figure 9, modified concrete latex particles are tightly packed together without forming a continuous latex film. From Figure 9(a), it can be seen that the latex particles only undergo slight deformation; from Figure 9(b), it can be seen that the latex particles have hardly undergone deformation; from Figure 9(c), it can be seen that a large number of latex particles are tightly packed together; under greater external forces, it can be seen from Figure 9(d) that the tightly packed latex particles undergo significant deformation. The structure of this latex greatly enhances the toughness of cement-based materials, which is beneficial for improving the flexural strength. This proves that when the content of carboxylic butylene styrene latex is 15%, its flexural strength is better.

Figure 9 Morphological structure of modified concrete latex particles, (a) carboxybutylbenzene content is 5% (b) carboxybutylbenzene content is 10% (c) carboxybutylbenzene content is 10% (d) carboxybutylbenzene content is 20%



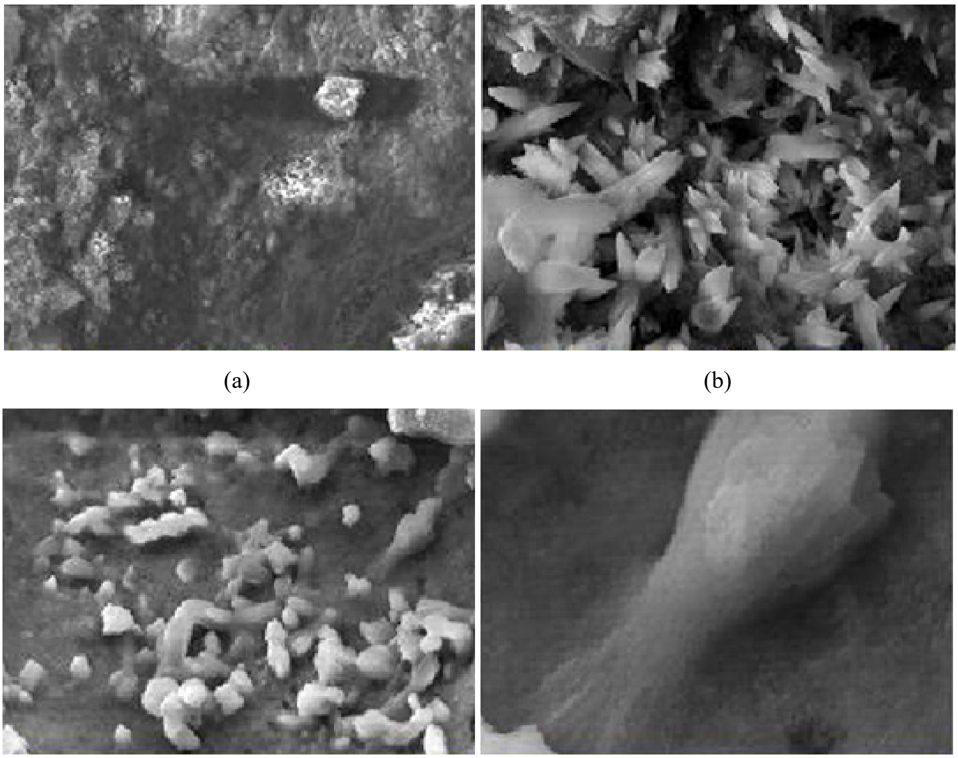
(a) (b) (c) (d)

3.7.4 The pore structure of modified concrete

Based on the above physical and mechanical test results, a modified concrete specimen with a carbon butylene styrene latex content of 15% was selected for in-depth research. The pore structure was measured as shown in Figure 10.

As shown in Figure 10(a), a large number of conical particles exist in the holes in the image. Figure 10(b) is an enlarged version of Figure 10(a), from which it can be seen that many conical particles are loosely filled in the holes; from Figure 10(c), it can be seen that there are also many loosely stacked cherry blossom cluster like particles in these pores. Figure 10(d) is an enlarged version of Figure 10(c), which can enhance the compactness, improve the impermeability of concrete, and significantly reduce its water absorption.

Figure 10 Hole structure diagram in modified concrete, (a) cone-shape granule of the pore (b) magnification of the pore (c) the tasset bundle-shaped particles of the pore (d) magnification



(a) (b) (c) (d)

3.7.5 Modified concrete composite structure

Select a modified concrete specimen with a carbon butylene styrene latex content of 15%, and measure the composite structure of the modified concrete as shown in Figure 11.

As shown in Figure 11, in improving the microstructure of concrete, it is sometimes possible to observe a combination of several structures simultaneously. From Figure 11(a), it can be seen that there are tree trunk like structures and latex film structures in the modified concrete. The latex film forms an interpenetrating structure with the cement hydration products, and there are also conical particles. The enlarged scanning electron microscope photo is shown in Figure 11(b), and this composite structure has a synergistic effect on improving the performance of cement-based materials.

4 Conclusions

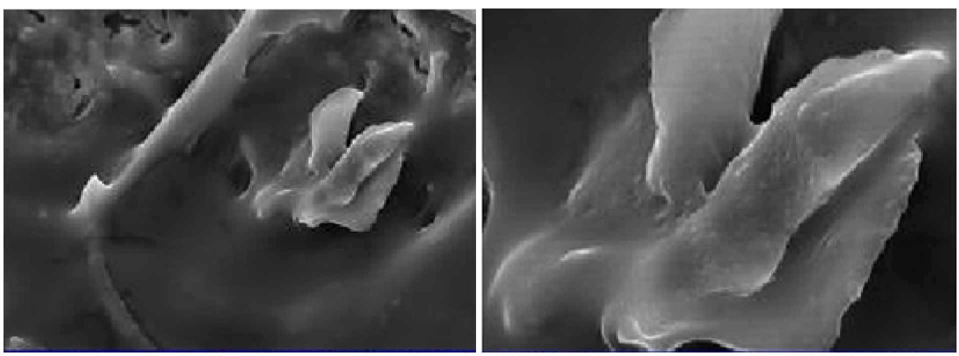
By analysing the microstructure of carboxylic butadiene styrene latex modified concrete, the following conclusions can be drawn:

1 The dendritic structure can greatly enhance the toughness of concrete materials and improve their flexural strength. When its dosage reaches 15%, its dendritic structure has the maximum amount, which can enhance the performance of modified concrete and improve its flexural strength.

2 The tightly packed latex particles in improved concrete can form a latex film under certain conditions, and the more they are added, the stronger their impermeability. Therefore, when the content of carboxylic butylene styrene latex reaches 20%, its impermeability is stronger.

3 When the content of carboxylic butylene styrene latex is 15%, the modified concrete has better performance, minimum water reduction rate, higher volume density value, and there are tree like structures and latex film structures inside. The latex film and cement hydration products form an interpenetrating network structure, and there are also conical particles, which improves the application performance of concrete.

Figure 11 Composite structure of modified concrete, (a) dendritic structure (b) conical particle structure



(a) (b)

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