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The waterproofing characteristics of polymer sodium carboxymethyl-cellulose

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Abstract

The mechanism of waterproofing of sodium carboxymethyl-cellulose is still unknown. In this project some special samples at the ages of 7 and 28 days were tested by means of scanning electron microscope, mercury intrusion porosimeter, and infrared absorption spectrum analyses. A number of filmy matters were found in hardened cement paste combined with sodium carboxymethyl-cellulose. The film was smooth and transparent, and matured well with hydration products. The whole system was seemingly divided into a lot of small areas by the film net. The waterproofing mechanism of the polymer is discussed according to the results of the test. Published by Elsevier Science Ltd.

Keywords: Filmy matters; Waterproofing; Hydration products; Cement paste; Polymer

1. Introduction

In general, hardened cement paste is a kind of porous material with many capillary voids. A lot of reports have shown that the pores can be choked up by polymers if the paste is added with a small quantity of soluble polymer during mixing [1–4]. Therefore, some characteristics of the material will be changed.

Sodium carboxymethyl-cellulose (SCMC) is one of components in some high-efficient water repellents and has an obvious effect on waterproofing [5–8]. However, the waterproofing mechanism of the polymer is still unknown. On the basis of previous research [9], this project hoped to find the waterproof characteristics of the polymer by a series of contrasting tests with the different instruments.

2. Methods

The raw materials were the same as those used by Lu et al. [9]. SCMC was mixed with ordinary Portland cement according to a special proportion reported previously [9]. Sample O was a basic preparation without SCMC. Samples A and B were preparations with 1.0 or 0.5% SCMC added (by weight of cement), respectively, on the basis of sample O. The water/cement ratio was 0.36. About 0.4% (by weight of cement) surfactant SN-2 should be added into the paste to keep it from serious flocculation before setting [10].

All samples were cured under a special standard condition to a definite date, 7 and 28 days. Then, they were put into pure alcohol to discontinue hydration reaction. A series of experimental determination and analyses were carried out by means of scanning electron microscope, mercury intrusion porosimetry, and infrared absorption spectrum.

3. Results and discussion

3.1. Morphology of SCMC

Many filmy matters occurred in samples A and B, but they did not exist in sample O. According to the original components of the samples, the filmy matter was composed of polymer SCMC. Its typical morphologies in hardened cement paste are shown in Figs. 1 and 2.

There was more SCMC content in sample A then in sample B; thus the amount of film was greater in sample A than in sample B. The film could be found easily at the pores in the structure of the matrix. It was like bedding or a sheet, covering or sticking on the walls of pores (Fig. 2b). Some of the film was standing at the entrances of holes, and therefore the effective dimension of the hole was decreased (Fig. 1b). Some films had matured with hydrates of cement, but they still held their own special

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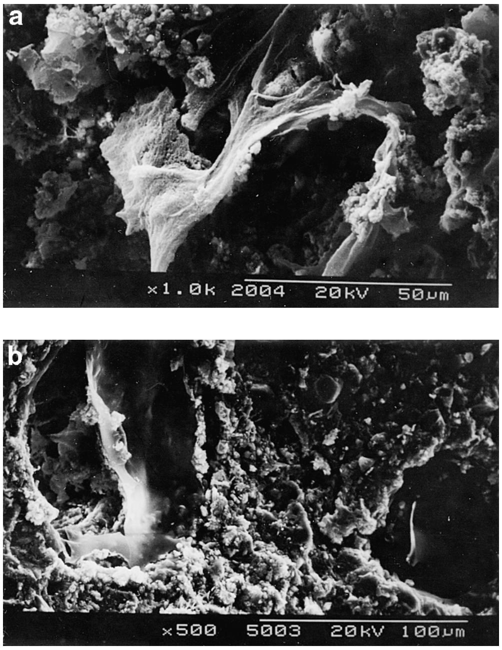

Fig. 1. Typical morphologies of the filmy matter, composed of polymer SCMC, in hardened cement paste A (a) for 7 days, (b) for 28 days.

filmy form. Under the range of vision of the electronic microscope, it could be found that the whole system was seemingly divided into a lot of small districts (like chambers) by the filmy matters (Fig. 3).

The surface of the film in samples A or B cured for 7 days was smooth and plain. However, in some samples A or B cured for 28 days, some film had been penetrated by

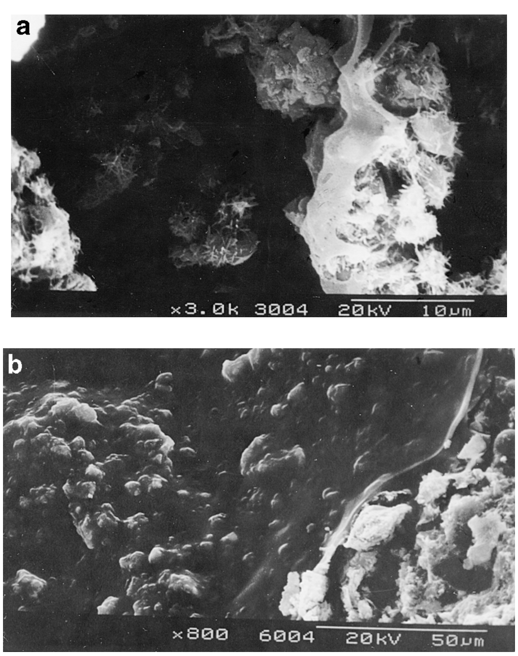

Fig. 2. Typical morphologies of the filmy matter, composed of polymer SCMC, in hardened cement paste B (a) for 7 days, (b) for 28 days.

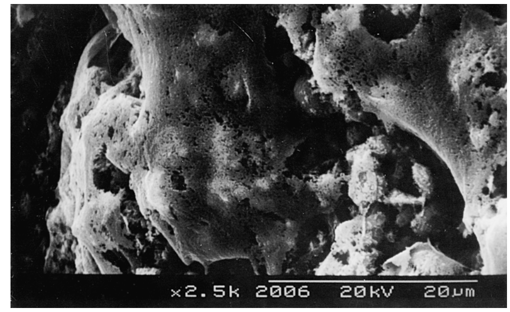

Fig. 3. The system, seemingly divided into a lot of small districts (like chambers) by the filmy matters in sample A, as seen under the electronic microscope.

hydrates from the bottom of the films and the hydration products appeared spread out, but they were tiny and sparse (Fig. 4).

3.2. Pore analysis

From the mercury intrusion porosimetry results, the characteristic peak of sample O without SCMC was constantly at the range between 0.1 and 0.01 μm (pore radius),whether it was cured for 7 or 28 days (Fig. 5). It is worth noticing that in sample B with 0.5% SCMC added, there was not only a characteristic peak, the same as that in sample O, but also a special peak that was at the region between 1 and 0.1 μm (pore radius) (Fig. 6). Further, in sample A with 1.0% SCMC the status had fundamentally changed. A big special peak (its intensity was 2.90) between 1 and 0.1 μm (pore radius) occurred in sample A at the age of 7 days (Fig. 7). However, at the age of 28 days the intensity of the peak has greatly decreased and a new peak had grown at the region between 0.1 and 0.01 μm (pore radius) (Fig. 8), the intensity of which was obviously different from that in sample O or B. At the age of 28 days, it was 1.37, 6.862, or 2.024. As was demonstrated, the addition of SCMC resulted in a change of the pore radii from smaller to greater. This moving status would be especially obvious with the greater addition of SCMC in the matrix.

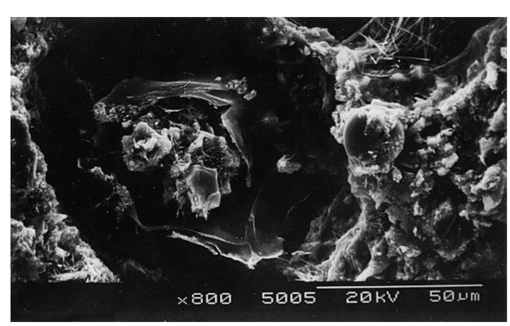

Fig. 4. Hydration products appeared spread out, but they were tiny and sparse.

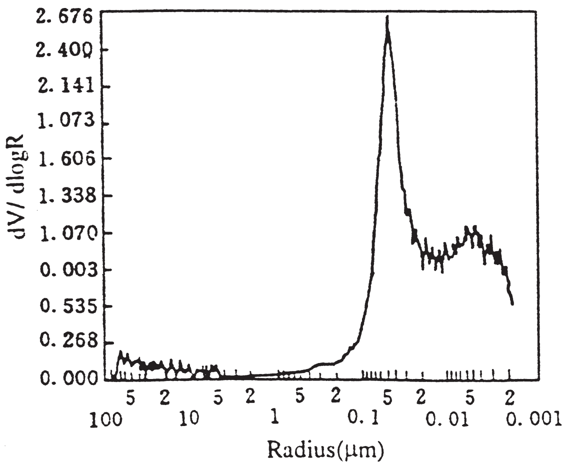

Fig. 5. Pore size distributions of sample O at 7 days.

The total porosity measurement also supported this reasoning. The numerical values of total porosity (7 days, 34.53%; 28 days, 28.82%) in sample O without SCMC were the lowest of all. Those in sample B (7 days, 35.98%; 28 days, 32.82%) were among the middle measurements. The structure in sample A with a greater amount of SCMC added was porous and the value of porosity was the highest (7 days, 45.05%; 28 days, 35.27%).

3.3. Screen function of SCMC film on waterproofing

According to the results of total porosity, if a small amount of SCMC was added into the system during mixing, porosity in the system did not decrease, but instead increased. The results from mercury intrusion porosimetry showed that the presence of SCMC in the system would bring about a new pore area, occurring at the district between 1 and 0.1 μm (pore radius). Moreover, the increase of SCMC content in the system would synchronise the increase of peak intensity of the new pore (Figs. 6, 7, and 8).

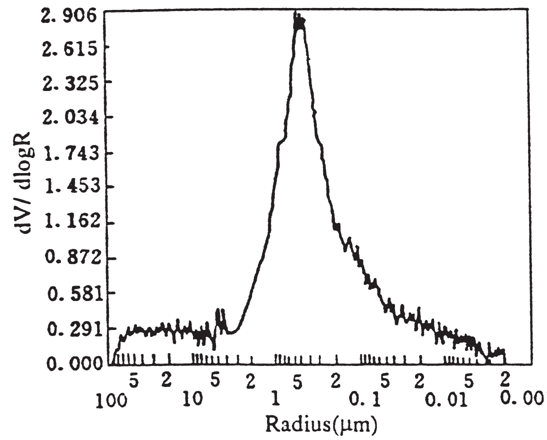

Fig. 7. Pore size distributions of sample A at 7 days.

The repeated finding and verification from each of these instruments mentioned above have made us consider if the previous view that a polymer will choke up the pores in the system as a main form of its waterproofing is fully correct. In other words, to what degree is the previous view true? From Fig. 1b the efficacious dimension of the hole was decreased by the polymer film standing at the entrance of the hole. However, within the range of view under scanning electron microscope, many pores are still open. Even though those pores were choked up by the film, they are not fully sealed. Therefore, the proposition of the form, that a polymer would seal up pores and increase waterproofing function, may be not very strict.

However, the waterproofing function of polymer-cement concrete is better than normal concrete without polymer, and the water repellent in which SCMC is a basic raw material for waterproofing is very effective. How does the polymer SCMC work in the system?

This polymer is soluble in water, and its molecule can diffuse at will with the help of movement of water mole-

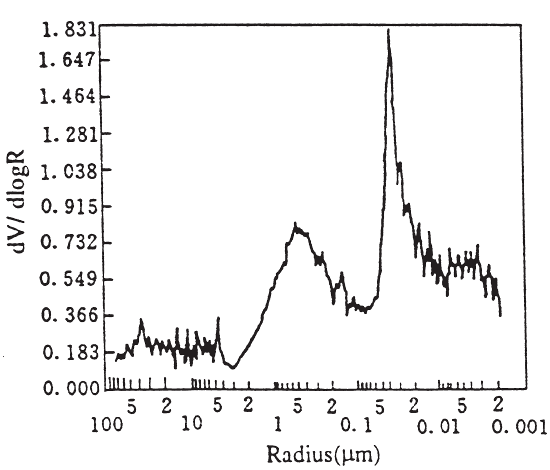

Fig. 6. Pore size distributions of sample B at 7 days.

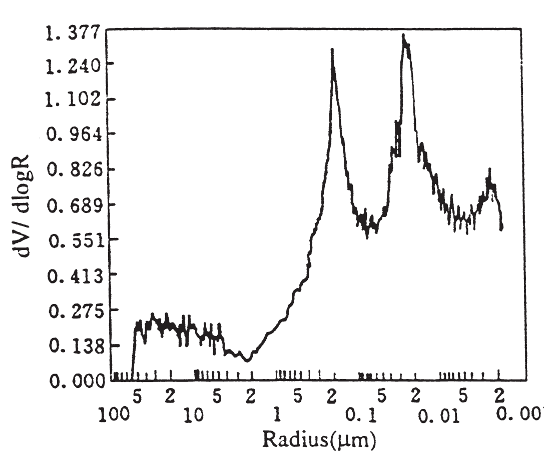

Fig. 8. Pore size distributions of sample A at 28 days.

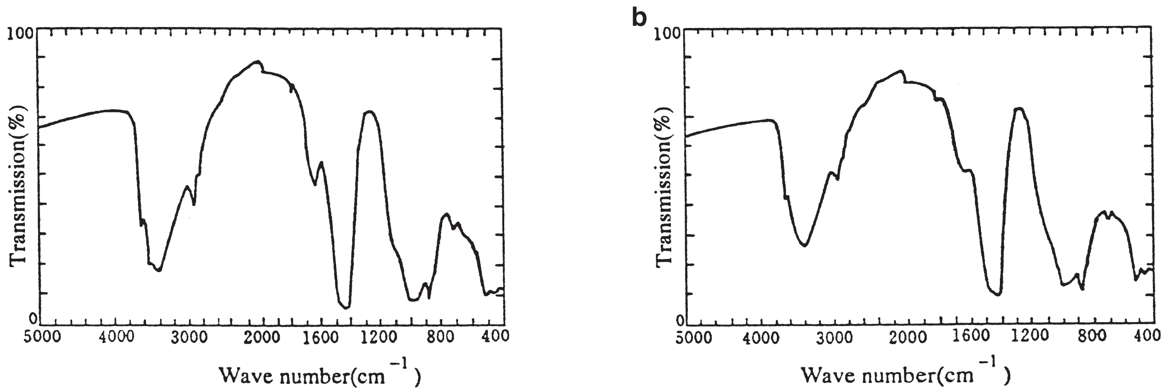

Fig. 9. Results from infrared absorption spectrum: (a) sample O, (b) sample A.

cules. Therefore, matters of the polymer are in every area of the system and will grow with hydration products. This means that after drying the film of polymer SCMC will exist in company with hydrates. In the range of this project, the forms of transmission peaks in all samples with or without SCMC added, from infrared absorption spectrum results, are essentially about the same (Fig. 9). However, it should be noticed that this polymer in the system showed its own special morphology of filminess, which is entirely different from the shape of the hydrate, and has formed a single phase in the matrix. Judging from the point of view of chemical absorption, the polymer can be a shape of surface filminess or can be a form of solid status. In this research project the single phase of polymer SCMC was found to be filmy.

In hardened cement paste the single phase of SCMC is tightly connected with the matrix. The whole system is divided into a lot of small waterproofing spaces by the film net. They are just as many sealing chambers in an aircraft-carrier. Water will not easily enter into other chambers even though one or several chamberlets have been destroyed.

The film net effectively cuts off capillary function in the matrix. As a result, the diffusion of water will become more difficult in the structure. The film tightly sticks on the wall of a pore or covers the bottom of a pore. Therefore, the film has a double function. One function is that water will hardly remain in the pore for long, due to the smooth surface and continuance of the film. The other function is that water will hardly penetrate the film into other spaces in a short time because of the high density of this organic film.

It goes without saying that the screen function of SCMC film on waterproofing should be in close relationship with a good condition of sealing status by the organic film in the system. Overly low amounts of polymer SCMC in the system or overdeflocculation from surfactant will make the film net of the polymer become discontinuous.

4. Conclusions

1. Soluble polymer SCMC will exist in a filmy shape in the structure of hardened cement paste. The film is tightly connected with the matrix, forming a monoblock structure. The whole system is divided into a lot of small spaces by the film net. Three-dimensional film net will effectively cut off capillary function in the matrix to increase the difficulty of water diffusion in the structure.
2. The presence of polymer SCMC in the system will cause a new pore in the district between 1 and 0.1 μm (pore radius) to occur in the structure; as a result, the total porosity will be increased. However, the screen function of the organic polymer film will efficiently resist penetration of water due to its smooth surface, continuance, and high density.
3. This research project found that some pores in the structure had been choked by a part of the polymer, but many pores were still open. Therefore, the screen function of the polymer film on waterproofing may be the main repellent form of polymer SCMC.

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