Various Filmed Effects on the Surface of Cement-based Materials Loading with Bacteria Induced by Biomineralization in Different Interventional Modes of CO_2

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ABSTRACT

Capturing and fixing CO_2 is a significant method to solve the problem of globe greenhouse effect. Inspired by the cure of concrete with CO_2, cement-based materials are types of mediums to fix and consume CO_2 effectively. Taking advantage of buildings existing extensively, loaded with bacteria which can secrete carbonic anhydrase on the surface of cement-based materials. In this way, captured CO_2 from the air and mineralized it into calcium carbonate. Meanwhile, compactness of cement-based materials surface could be improved. Thus, the anti-erosion ability of cementitious matrix and durability of buildings were enhanced. This researchmainly delvesthe protective effect of mineral filminduced by biomineralization mechanism in different interventional modes of CO_2. The results demonstratethat, high concentration of CO_2 contributes to dense, continuous and flat calcite film forming rapidly on the surface of cement-based material. The coefficient of capillary suction of specimensurface decreases more than 80% after filming.

1.INTRODUCTION

Calcite film formed by biomineralization mechanismhas been regarded as an environmental-friendly and economic material which had a promising potential for protecting the surface of coating material[1]. Carbonic anhydrase (CA) is a kind of zinc metalloenzyme which distributes widely in cells of animals and plants as well as certainmicroorganism. It has an extraordinary catalytic effect in the known biocatalyst, apparently accelerating carbon dioxide hydration reaction under ambient temperature and pressure. This research mainly delves the protective effect of mineral film induced by biomineralization mechanism in different interventional modes of CO_2.

2. MATERIALS

The materials used for testing were cement paste with Portland cement and w/c ratio of 0.45.The specimens were casted into 40mm cube.Bacillusmucilaginous was chosen to provide carbonic anhydrase, cultured by medium with nitrogen [2]. By means of spectrophotometer testing the optical density (OD) of the bacterial liquid, adjusted its concentration into 1×10^8 cell/ml.Dissolved the bacterial powder (1×10^{11}cell/g) by medium, so as to prepare solution of bacterial powder with concentration of 1×10^8cell/ml.

3. METHODS

The testing methods are listed in the Table 1 and shown in Figure 1.

Table1: Different interventional modes of CO_2&experimental conditions

Interventional modes	Volume fraction	Time	Blank group	Bacterial liquid group	Bacterial powder group
Air	0.03%	1 d	50ml medium	50ml Bacterial liquid (1×10^8cell/ml)	50ml solution of bacterial powder (1×10^8cell/ml)
Concrete Carbonation Chamber	20%	1 d			
Aerate pure CO_2directly	100%	2 h			

Temperature: 25℃±2℃, R.H.:75%±10%.

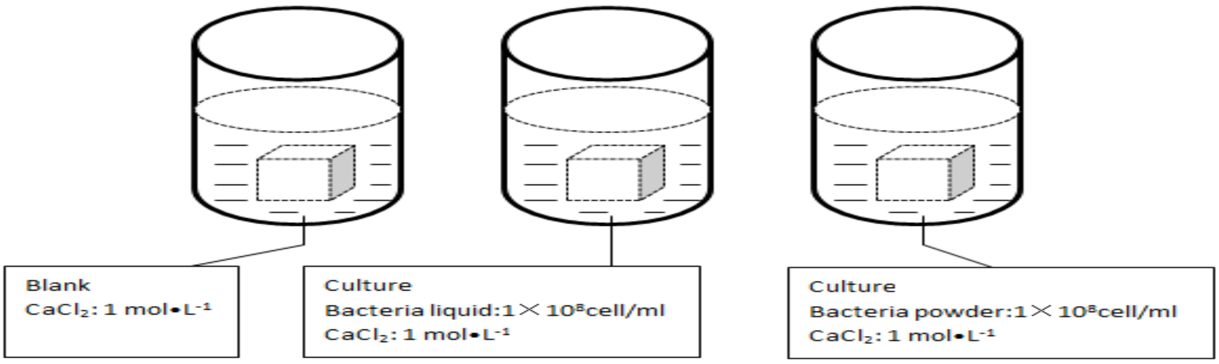


Figure 1: Specimens immerged in reaction solution

4RESULTSAND DISCUSSION

On the whole, all specimens of three groups in different interventional modes of CO_2 follow a common trend. That is coefficient of capillary suction decreases along with the increase of the concentration of CO_2. It is indicates that calcite film gets thicker and denser, which can protect the cement-based materials better, when the concentration of CO_2 is increased.(Figure2)

The SEM micrographs of the specimen surface immersed into the bacterial liquid in different interventional modes of $CO_2$are shown in figure 3.The concentration of CO_2 is only 0.03% in the air. Biomineralization develops slowly in this condition, so the calcium carbonate crystal stacks loosely and presents a state of discontinuous particle. The size of the calcium carbonate crystal is large. Its shape is irregular and has obvious angularity, which goes against compactness of calcite film.(Figure 3)Since the concentration of CO_2 in the chamber is about 20%, the protective effect of film improves slightly. Calcite film presents in a schistose state. It has a rudiment of film. (Figure 3b) The calcite film is continuous and dense in this condition.The calcium carbonate crystal formed by biomineralization stacks compactly. The morphology of the calcium carbonate crystal is tinier and smoother.(Figure 3c)

Therefore, aerating pure CO_2 directly into the bacterial liquid has the best experimental effect, acquiring denser calcite film. In the meantime, its coefficient of capillary suction low to $9.19g/(m^2\cdot s^{1/2})$ and the relative decreased rate up to 84%, which can protect the cement-based materials effectively.

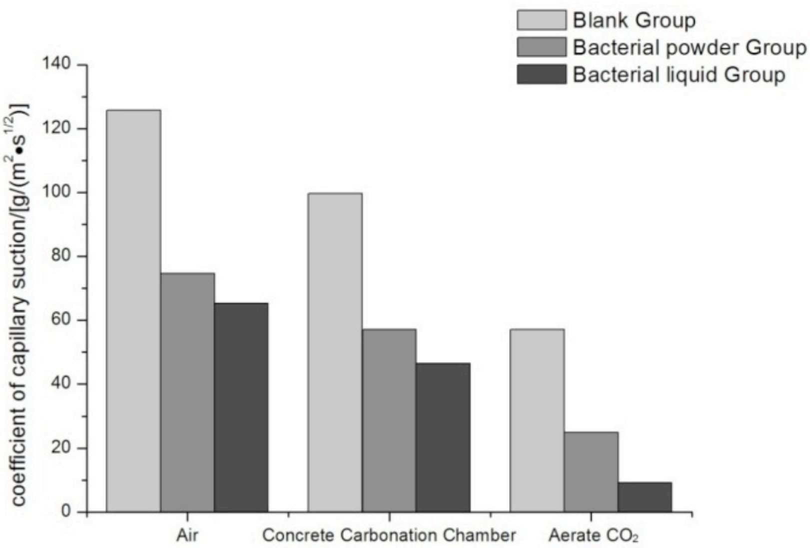
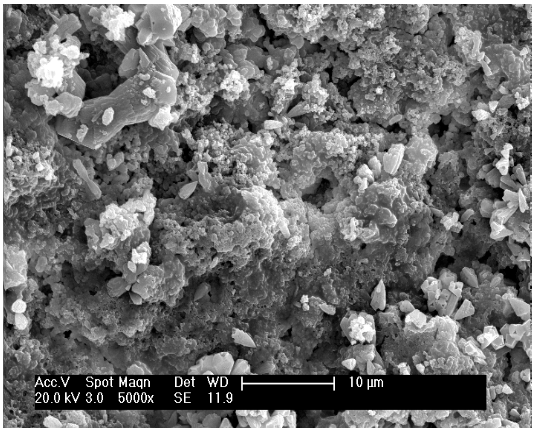
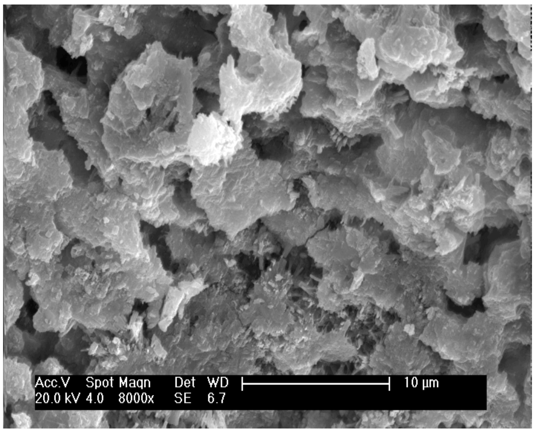


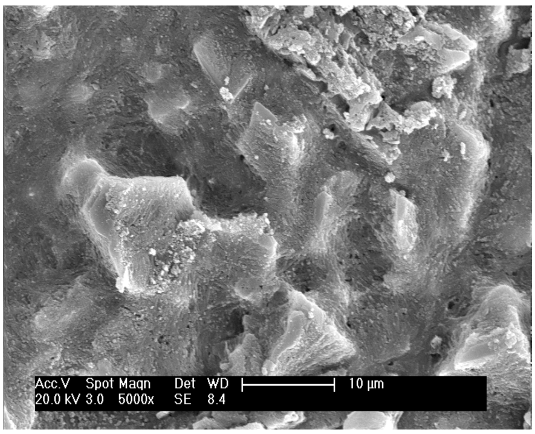
Figure2: Coefficient of capillary suction of cement specimens in different interventional modes of CO_2

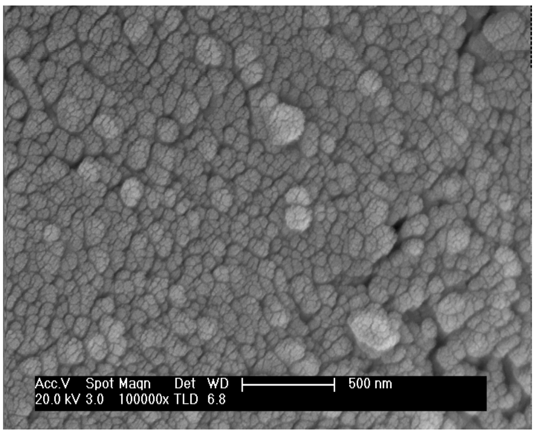


(a) 0.03% carbon dioxide concentration



(b) 20% carbon dioxide concentration





(c) 100% carbon dioxide concentration

Figure 3 Scanning electronic micrographs of the surface of cement-based materials under different curing environment

The SEM micrographs of the specimen surface immersed into the bacterial liquid with aerating pure CO_2 directly are shown in figure 3c.The size of calcium carbonate crystal is pretty tiny and its diameter is lower than 100 nm. The shape of calcium carbonate crystal is regular spheroid. In the high concentration of CO_2 condition, supersaturation of calcium carbonate and nucleation rate of calcium carbonate crystal are increased greatly during the initial reaction stage of biomineralization. With carbonic anhydrasecatalyzing, the reaction time can be shortensubstantially, leading to the growing time of calcium carbonate crystal decreasing greatly. Hence, there is no enough time for calcium carbonate crystal to grow up. In this condition, more complicatedmorphology and highly ordered nano-scaled calcium carbonate can be acquired[3].

5.CONCLUSIONS

Different interventional modes of CO_2 have various influences on the protective effect of calcite film, which depends on the concentration and dosage of CO_2. High concentration of CO_2 benefits to form calcite film rapidly. The film is continuous, dense and flat, and the relative decreased rate of coefficient of capillary suction is large. Nevertheless, low concentration of CO_2, such as the air condition, the film stacks loosely and the morphology is uneven. Its relative decreased rate of coefficient of capillary suction is quite small.

Calcium carbonate crystal formed in the low concentration of CO_2 presents a state of discontinuous particle. The size of the calcium carbonate crystal is large. Its shape is irregular and has obvious angularity, which goes against compactness of calcite film. Oppositely, calcium carbonate crystal formed in the high concentration of CO_2 is tinier and smoother, which is beneficial to compactness of calcite film.

Biomineralization mechanism has a vital enlightening role in capturing and fixing CO_2, offering an innovative method to solve the problem of globe greenhouse effect. Using cement-based materials loading with bacteria captures CO_2, achieving dual goals of fixing carbon and improving anti-erosion ability of cementitious matrix.

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