M. Yang et al. (Eds.)

doi:10.3233/ATDE230785

Carbonation Property of Concrete Prepared by Microorganism Supported on Coral Reef

Ya DONG [a,1], Anquan LIANG [a], Wei SHU [b], Zejiang ZHANG [c] and Zhihui ZHOU [a]
[a] Zhejiang Communications Construction group Co., Ltd. China
[b] Tongxiang Communications Construction Investment Group Co. Ltd. China
[c] Zhejiang Transportation Science Engineering Management Co., Ltd., China

Abstract. The crack of concrete will seriously affect the stability and durability of its structure. The microbial mineralization and crystallization technology can effectively improve the crack of concrete. In order to improve the influence of microbial self-healing technology on the mineralization and crystallization of concrete cracks, the South China Sea coral reef calcrete sand was used as a new porous material to support Pasteurella. The microbiological mineralized products were analyzed by SEM-EDS. The results showed that the microbiological mineralized products were mainly calcium carbonate crystals. The carbonization test was carried out to verify the repair effect of the resin on concrete cracks. The results showed that the content of bacteria carrier should not exceed 10%. When the bacterial carrier content is 10% and the mineralization reaction product content is 3%, the carbonization resistance of cement mortar specimen is improved most obviously. This research provides help for the engineering application of concrete crack repair and has high application value.

Keywords. Support material, microorganism, self-healing property, carbonization performance

1. Introduction

Concrete is widely used in various engineering fields. Under the action of load and deformation factors, it is easy to crack and form cracks, which become the transmission channel of moisture, erosion ions and other substances, leading to the rust of steel bars and the degradation of structural bearing capacity resulting in safety risks [1-3]. Repairing cracks is the key to solve the durability problem of concrete structures. In recent years, the microbial self-repair technology of concrete cracks has gradually become the research focus of scholars at home and abroad [4-11]. Microbial self-healing coagulation technology has the characteristics of environmental friendliness, no pollution, ecological sustainability, good compatibility with concrete and high durability, but there are some problems such as low long-term microbial activity and insufficient self-healing effect. Jonkers et al. [12] directly added Bacillus pseudomonas and Bacillus coriolis into concrete respectively, and the results showed that the pore

[1] Ya DONG, Corresponding author, Zhejiang Communications Construction group Co., Ltd. China; E-mail: 406779136@qq.com.

size of cement matrix inside concrete would gradually decrease with the progress of hydration reaction, which would affect the living space of microorganisms. Achal et al. [13] added Bacillus giant directly into mortar and concrete matrix, and the study found that the survival rate of microorganisms decreased significantly from 7d to 28d after incorporation.

In this paper, the South China Sea coral reef was selected as the carrier material for the first time to study the self-healing effect of microorganisms in concrete after loading, and the carbonation performance was used as the evaluation index.

2. Materials and Experiments

2.1. Materials

The cement was 42.5 ordinary Portland cement. Coarse aggregate was made of macadam aggregate with grading size of 9.5~13.2, 13.2~16 and 16~19 mm. The sand was made of Zhoushan common building sand (particle size range 0.075~2mm).

Sporpsarcina pasteurii was selected in this paper, which was from China General Microbial Species Preservation and Management Center (CGMCC). The strain number was 1.3687. Bacillus Pasteurii was aerobic and alkali resistant, Gram positive and had good alkali resistance. The cells were characterized by high temperature resistance, rapid recovery and strong secreting enzyme ability. The diameter of the cells was 1-2 μm, the length was about 2-3 μm, and the spore was round, with a diameter of 0.4~1.2μm. The culture of microbial strains goes through five steps, including high temperature sterilization, inoculation, constant temperature oscillation, testing the activity of enzymes contained in the bacterial solution, and taking out the bacterial solution [14].

The supporting materials were from coral reefs of Nansha Islands, and were machined into 0~5mm particle size and screened into 7 groups of particle size: 0~0.075, 0.075~0.15, 0.15~0.3, 0.3~0.6, 0.6~1.18, 1.18~2.36 and 2.36~5mm. Rinse and soak in fresh water, then dry and steam sterilize. Bacillus pasteurelli was cultured for 24h, and the calcareous sand carrier of coral reef was put into a vacuum adsorption pot for negative pressure adsorption, and the calcareous sand was yellowish in color after adsorption of the bacteria solution [14].

3. Test Method

3.1. Accelerate Carbonization Test

According to Test Method for Long-term Performance and Durability of ordinary concrete (GB/T 50082-2009), the specimen accelerated carbonization test was carried out, and the technical parameters of the carbonization box were set as curing temperature of 20℃, humidity of 70% and carbon dioxide concentration of 20%. When the vernier caliper was used to measure the carbonation depth of each point, the reading accuracy was 0.1mm. The carbonation depth of each cement mortar specimen was calculated according to formula (1):

$$d_t = \frac{\sum_{i=1}^{n} d_i}{n} \tag{1}$$

Where, d_t is the average carbonization depth of cement mortar specimen after accelerated carbonization t; d_i is the carbonation depth of each measuring point; n is the number of carbonation measurement points.

Table 1 shows the mix ratio design of cement mortar. In the mixing process, calcium lactate and urea (mass ratio 3:2) were added to produce the product (N) of mineralization reaction, as well as the pre-prepared bacteria-containing carrier (BS). The mix ratio of mortar specimen is shown in table 1.

Table 1. Mix proportions of cement mortar specimen.

NO.	Cement (g)	Sand(g)	Water(g)	m_{BS}(g)	m_N(g)
A0	45	135	22.5	0	0
A1	45	135	22.5	0	0.45
A2	45	135	22.5	0	0.9
A3	45	135	22.5	0	1.35
B0	45	135	22.5	2.25	0
B1	45	135	22.5	2.25	0.45
B2	45	135	22.5	2.25	0.9
B3	45	135	22.5	2.25	1.35
C0	45	135	22.5	4.50	0
C1	45	135	22.5	4.50	0.45
C2	45	135	22.5	4.50	0.9
C3	45	135	22.5	4.50	1.35
D0	45	135	22.5	6.75	0
D1	45	135	22.5	6.75	0.45
D2	45	135	22.5	6.75	0.9
D3	45	135	22.5	6.75	1.35

3.2. SEM and XRD

The sample size is 5×5×2mm. The sample was cleaned and dried. After 90s gold spraying treatment, it can be taken out and placed in scanning electron microscope equipment for scanning observation and energy spectrum analysis.

4. Results and Discussion

4.1. Morphology Analysis

The microscopic morphology and elemental composition of the calcium carbonate precipitate were further analyzed by SEM and EDS, and the test results were shown in figure 1. The results show that the sediments produced under the condition of calcium source contain C, O and Ca elements, and the sediments induced by microbial mineralization are calcite type calcium carbonate crystals. The morphology of calcium carbonate crystals in figure 1 is spherical or spherical aggregate, and the surface looks smooth without obvious enrichment of holes or pits.

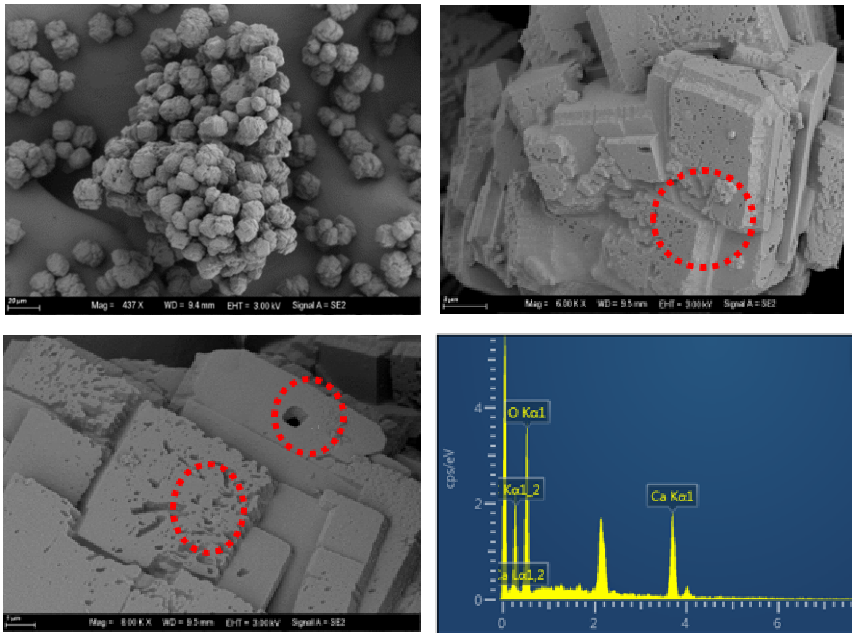

Figure 1. Microscopic morphology of mineral precipitate induced by bacteria.

4.2. Carbonation Depth of Microbial Self-repairing Concrete Specimens

Figure 2 shows the results of the influences of the content of bacterial-bearing carrier and substrate on the carbonation depth of microbial self-healing cement mortar specimens.

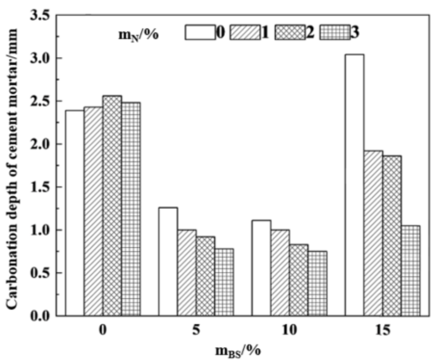

Figure 2. Carbonation depth of cement mortar specimen with different bacterial carrier.

As can be seen from figure 2, for Group A specimens with 0% bacterial carrier content, the carbonation depth of specimens has no significant change when the mineralization reaction product content increases from 0% to 3%. For group B, C and D specimens with bacterial carrier content, the carbonation depth gradually decreases with the increase of the mineralization reaction product content. When the bacterial carrier content was 15%, the carbonation depth of specimens with 0% bacterial carrier content increases. When the substrate content increased from 0% to 3%, the carbonization resistance depth of the specimen decreased by 67% from 3.04mm to 1.05mm. When the bacterial carrier content was 5% and 10%, similar rules were also observed, indicating that the carbonization depth of the specimen would decrease with the increase of the mineralization reaction product content when the bacterial carrier content was constant.

For specimens B and C, the carbonation depth of specimens increased with the increase of bacterial-containing carriers when the content of bacterial-containing carriers exceeded 10%. Therefore, the carbonation depth of specimens can be effectively reduced with the addition of bacterial-bearing carriers and mineralized reaction products in a suitable range. When the bacteria carrier content was 15% and the mineralization reaction product content was 3%, the carbonization resistance of the specimen was improved best.

5. Conclusion

(1) The carbonation depth of the microbe self-repairing cement mortar specimen with bacteria carrier can be reduced to 1.05m.

(2) When the content of bacterial carrier was less than 10%, the carbonization depth of the specimen showed a nonlinear decrease with the increase of the content of bacterial carrier and substrate. The carbonization resistance of the specimen was improved obviously when the bacteria carrier content was 10% and the mineralization reaction product content was 3%.

(3) The content of bacterial carrier should not exceed 10%. When the content of bacterial carrier was 10% and the content of mineralization reaction product was 3%, the carbonization resistance of cement mortar specimen was improved most obviously.

References

[1] Min W, Johannesson B, Geiker M. A review: Self-healing in cementitious materials and engineered cementitious composite as a self-healing material. Construction and Building Materials. 2012; 28(1): 571-583.

[2] Boquet E, Boronat A, Ramos-Cormenzana A. Production of calcite (calcium carbonate) crystals by soil bacteria is a general phenomenon. Nature. 1973; 246(5434): 527-529.

[3] Whiffin VS. Microbial CaCO3 precipitation for the production of Biocement. Western Australia: Murdoch University, 2004.

[4] Zhang W, Zheng Q, Ashour A, et al. Self-healing cement concrete composites for resilient infrastructures: A review. Composites Part B Engineering. 2020: 107892.

[5] Idiart AE, López CM, Carol I. Chemo-mechanical analysis of concrete cracking and degradation due to external sulfate attack: A meso-scale model. Cement & Concrete Composites. 2011; 33(3): 411-423.

[6] Branko J, Pacheco J, Schlangen E. Lattice modeling of chloride diffusion in sound and cracked concrete. Cement and Concrete Composites. 2013; 42: 30–40.

[7] Achal V, Pan XL, Ozyurt N. Improved strength and durability of fly ash-amended concrete by microbial calcite precipitation. Ecological Engineering. 2011; 37(4): 554-559.

[8] Ghosh S, Biswas M, Chattopadhyay BD, Mandal S. Microbial activity on the microstructure of bacteria modified mortar. Cement and Concrete Composites. 2009; 31(2): 93-98.
[9] Muynck WD, Belie ND, Verstr Ae Te W. Microbial carbonate precipitation in construction materials: A review. Ecological Engineering. 2010; 36(2): 118-136.
[10] Sierra-Beltran MG, Jonkers HM, Schlangen E. Characterization of sustainable bio-based mortar for concrete repair. Construction & Building Materials. 2014; 67(C): 344-352.
[11] Wiktor V, Jonkers HM. The potential of bio-based repair system to increase the durability of repaired concrete structures. Microstructural-related Durability of Cementitious Composites. 2012.
[12] Jonkers HM, Thijssen A, Muyzer G, et al. Application of bacteria as self-healing agent for the development of sustainable concrete. Ecological Engineering. 2010; 36(2): 230-235.
[13] Achal V, Pan X, OZyurt N. Improved strength and durability of fly ash-amended concrete by microbial calcite precipitation. Ecological Engineering. 2011; 37(4): 554-559.
[14] Li T, Lai XY, Huang H, et al. Study on crystallization effect of new immobilized materials. Industrial Construction. 2022; 52(11): 84-90.