Research on Inhibitory Effect of Green Algae of C30 Coral Aggregate Concrete Surface with Different Mortar Coatings

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Abstract. In this paper, maximum fluorescence value was first applied to indicate the anti-green algae properties of concrete, the lower the maximum fluorescence value, the better the anti-green algae properties of concrete. This study investigates the effect of strength grade of mortar coating and types of hydrophobic materials and admixture on the fluorescence value of C30 coral aggregate concrete. The results show that adding a certain proportion of hydrophobic material directly can reduce the maximum fluorescence value of coral aggregate concrete. Using mortar of different strength grades as concrete coating can also reduce the fluorescence value of concrete surface. The higher the strength grade of mortar is, the greater the decrease of the maximum fluorescence value will be. Using mortar mixed with hydrophobic material as coating can minimize the maximum fluorescence value of the concrete surface of coral aggregate concrete. In general, the maximum fluorescence value of M100 mortar coating with 5% of the total mass of cementitious material can be reduced to the minimum. Compared with the C30 coral aggregate concrete without hydrophobic agent, the maximum fluorescence value can be reduced by 75.4%.

1. Introduction

In recent years, in order to solve the problem of lack of natural aggregate in the construction of offshore concrete projects, researchers at home and abroad have gradually carried out relevant research on the preparation of concrete by using the relatively rich coral aggregate in offshore islands and reefs, and achieved certain research and application results [1-5]. It is found that coral aggregate can be used to produce concrete, but the concrete prepared with coral aggregate usually has lower compressive strength, higher porosity, lower strength and poorer durability [6-8].

The humid and rainy climate of Ocean islands and reefs provides a favorable environment for the growth of cyanobacteria, so the phenomenon of cyanobacteria on the surface of concrete pavement and concrete wall is very prominent in these places. It has been reported [9–10] that the viscous substances secreted by cyanobacteria can reduce the friction of concrete pavement, increase the risk of pedestrians and driving, and some low pH media in the secreted substances aggravate the durability of concrete.

It is found that coating technology is an effective measure to solve the problem of marine biological and plant adhesion on the surface of concrete structures. Different from the organic coating, the mortar coating has the characteristics of good coordination and durability with the concrete. The
research on the prevention and control measures of blue-green algae on the concrete surface based on the mortar coating can provide a reference for the research and application of the prevention and control of blue-green algae on the offshore islands and reefs.

2. Material and Experimental

2.1. Material

P.O 42.5 cement used in this study is produced by Conch Cement Factory in Guangdong Province, with specific surface area of 345 m²/kg, initial setting time of 225 min, final setting time of 332 min, 3d mortar compressive strength of 20.1 MPa, 28d mortar compressive strength of 50.2 MPa. Fly ash is obtained from a power plant in Guangdong Province, with a 45μm sieve residue of 8%, a specific surface area of 390 m²/kg, a water demand ratio of 91%, and a sulfur trioxide content of 0.87%. Slag is used type S95, with a specific surface area of 430 m²/kg, fluidity ratio of 95%, and 28d activity index of 98%. Silica fume is produced by a factory in Guangxi Province, whose SiO₂ content is 92%.

Coral coarse aggregate (Figure 1) is obtained from an island in the South China Sea, with specific surface area of 2354 kg/m³, bulk density of 918 kg/m³, porosity of 61%, water absorption of 12.5%, and compressive strength of 3.72 MPa. Coral fine aggregate (Figure 2) is also obtained from the island, with specific surface area of 2500 kg/m³ and bulk density of 1169 kg/m³, porosity 53.4%, water absorption 8.9%. River sand used in this study is a continuous gradation, with a fineness modulus 2.6, mud content 0.5%, chloride ion content 0.01%, apparent density 2530 kg/m³. Polycarboxylates high performance water-reducing admixture (PCE) used in this study is light yellow liquid, with solid content of 30%, water reducing rate of 30%. Silane is one of the hydrophobic agents. It is a white powder with SiO₂ content of 23% and pH value of 7-8; antifreeze and waterproof alloy powder (HF) is another inorganic hydrophobic agent produced by a domestic company in China, it is a light gray powder.

2.2. Testing Mixes

Table 1 shows the test mix proportion of C30 coral aggregate concrete without any treatment and C30 coral aggregate concrete with hydrophobic agent. Cement in coral aggregate concrete is partially replaced with 0.5% and 1%GW, 3% and 6% HF by weight for all series concrete. In this study, the
mortar coating of different compositions will be applied on the surface of coral aggregate concrete to improve inhibition of green algae of concrete. The mortar coating test mix proportions are shown in Table 2. Cement in Mortar coating is replaced with 1% GW, 6% HF by weight.

**Table 1. Test mix proportion of coral aggregate concrete (kg/m³)**

| Sample | Cement | Fly Ash | Water | Coral stone | Coral sand | PCE | GW | HF |
|--------|--------|---------|-------|-------------|------------|-----|----|----|
| B1     | 291    | 109     | 302   | 692         | 726        | 2   | -  |    |
| B2     | 291    | 109     | 302   | 692         | 726        | 2   | 2  | -  |
| B3     | 291    | 109     | 302   | 692         | 726        | 2   | 4  | -  |
| B4     | 291    | 109     | 302   | 692         | 726        | 2   | -  | 12 |
| B5     | 291    | 109     | 302   | 692         | 726        | 2   | -  | 24 |

**Table 2. Test mix proportion of mortar coating (kg/m³)**

| Sample | Cement | Fly Ash | Silicone | Water | River sand | PCE | GW | HF |
|--------|--------|---------|----------|-------|------------|-----|----|----|
| M50    | 535    | 95      | 0        | 240   | 1130       | 7   | -  |    |
| M50G   | 535    | 95      | 0        | 240   | 1130       | 7   | 6.3|    |
| M50H   | 535    | 95      | 0        | 240   | 1130       | 7   | -  | 31.5|
| M100   | 800    | 140     | 60       | 180   | 1000       | 20  | -  |    |
| M100G  | 800    | 140     | 60       | 180   | 1000       | 20  | 10 |    |
| M100H  | 800    | 140     | 60       | 180   | 1000       | 20  | -  | 60 |

2.3. Details of Test Conditions

(1) The slump of basic performance concrete are measured in accordance with GB/T 50080 (2016), the fluidity test of mortar are measured in accordance with GB/T 50448 (2015), the strength test of mortar coating and concrete are measured in accordance with GB/T 50081 (2019).

(2) In this study the maximum fluorescence value is used to evaluate the Algal resistance performance of concrete. The earlier the maximum fluorescence value of concrete appears, the faster the growth rate of cyanobacteria on the concrete surface; the higher the maximum fluorescence value of concrete, the more the growth amount of cyanobacteria on the concrete surface. The culture system of cyanobacteria and the surface treatment of concrete specimens are as follows:

1) the culture of cyanobacteria species is inoculated in BG-11 culture medium with 5% o.d.750 in a triangular flask for aseptic culture, and the shaking speed of 70 rotations/min was maintained during culture. 4100k fluorescent tube is used as the light source, with the light intensity of 35 μmol·m⁻²·s⁻¹ (about 2000 Lux), and the photoperiod is 10L:14D, and the culture temperature was 25 ± 1 °C. The experimental algae were cultured to logarithmic growth stage, centrifuged at 4000rpm, and suspended in 1/3 BG-11 medium until the cell density was 10⁶/ml.

2) In the concrete anti algae test, put the concrete and mortar test blocks (100mm×100mm×100mm) into the standard curing room for 28 days, and then move them into the square plastic box with the length of 138mm, the width of 138mm and the height of 100mm respectively. Slowly pour the prepared algal solution into the plastic box until the algal solution of the test block buries 50% of the height of the test block. Put the plastic box in the same test chamber with the same light and temperature conditions as the algae culture to carry out the algae growth test on the concrete surface. At 9:00 a.m. every day, take the test block out of the algal solution and leave it for 1 hour until the surface is dried. Then test the fluorescence value of algal species on the surface of the test block. After the test, put the test block back to its original position. The fluorescence value was recorded by chlorophyll fluorescence imager as shown in Figure 3. The test of concrete algae is shown in Figure 4.
3. Results and Discussion

3.1. Basic Performance

The influence of the type and content of hydrophobic agent on the slump and 28d compressive strength of coral aggregate concrete is studied. Test results of slump and 28d compressive strength of coral aggregate concrete with different type and content of hydrophobic agent are shown in Table 3. It is shown that the type and content of hydrophobic agent have different effects on the slump of C30 coral aggregate concrete. The slump of concrete increases with the increase of GW. The slump of concrete increases 7.1% with 0.5% GW and 7.1% with 1% GW. The slump of concrete decreases with the increase of HF by 7.1% after adding 3% HF, and further decreases by 7.1% after adding 6% HF. Compared with coral aggregate concrete without hydrophobic agent, the 28d compressive strength of concrete mixed with 0.5% GW increased by 2.3%, and the 28d compressive strength of concrete mixed with 1% GW increased by 3.9%. The compressive strength of concrete increased by 1.6% after incorporation of 3% HF, and that of concrete in 28d increased by 4.9% after incorporation of 6% HF.

| Sample | Slump(mm) | 28d compressive strength (MPa) |
|--------|-----------|-------------------------------|
| B1     | 140       | 38.6                          |
| B2     | 150       | 39.5                          |
| B3     | 160       | 40.1                          |
| B4     | 130       | 39.2                          |
| B5     | 120       | 40.5                          |

Table 4 shows the influence of the type and content of hydrophobic agent on the fluidity and 28d compressive strength of mortar coating. The results show that the influence rule of the type and amount of hydrophobic agent on the fluidity of mortar coating is consistent with the influence rule of the slump of C30 coral aggregate concrete. For M50 mortar coating, the fluidity of mortar coating remains unchanged after mixing 0.5% GW, while the fluidity of mortar coating increases 1.7% after adding 1% GW. For M100 mortar coating, the fluidity of mortar coating decreases by 1.8% after incorporation of 3% HF, and by 5.4% after incorporation of 6% HF.
Table 4. Fluidity and 28d compressive strength of mortar coating

| Sample | Fluidity (mm) | 28d compressive strength (MPa) |
|--------|---------------|--------------------------------|
| M50    | 290           | 59.5                           |
| M50G   | 290           | 60.1                           |
| M50H   | 295           | 62.5                           |
| M100   | 280           | 112.6                          |
| M100G  | 275           | 113.5                          |
| M100H  | 265           | 115.3                          |

The 28d compressive strength of the mortar coating increased to different degrees after the incorporation of the two hydrophobic agents. Compared with the mortar coating without hydrophobic agent, the 28d compressive strength of the mortar coating increased by 1.0% after mixing 0.5% GW, and increased by 5.0% after mixing 1% GW. The 28d compressive strength of the mortar coating increased by 0.8% after incorporation of 3% HF, and increased by 2.4% after incorporation of 6% HF.

The effect of GW hydrophobic agent on the improvement of the micro morphology of the interface transition zone between concrete and mortar [11-12], which improves the compressive strength of concrete and mortar. The basic components of HF hydrophobic agents contain certain nano-scale inorganic particles, whose "micro-gradation" effect may be the reason for the strength enhancement of concrete and mortar.

3.2. Fluorescent Value
The fluorescent value test results of different coral aggregate concrete mix proportions are shown in Table 5 and Figure 5. The fluorescent value test results of different mortar coating mix proportions are shown in Table 6 and Figure 6. The thermal imaging corresponding to the maximum fluorescence value of mix proportion B1, B5, M50H and M100H is shown in Figure 7(a), (b), (c) and (d).

Table 5 and Figure 5 show that the fluorescence value of coral aggregate concrete at each test age decreases to different degrees after the addition of hydrophobic agent. The maximum fluorescence value of the concrete surface decreased with the increase of the amount of GW as the hydrophobic agent. The maximum fluorescence value of the concrete surface decreased by 10.4% after adding 0.5% GW, and decreased by 29.7% after adding 1% GW. The fluorescence value of concrete decreases with the increase of the content of hydrophobic agent HF, and the maximum fluorescence value of concrete surface decreases by 20.6% after adding 3% GW, and decreases by 50.9% after adding 6% HF. Comparatively speaking, the maximum fluorescence value of C30 coral aggregate concrete decreased more when 6% hydrophobic agent HF was added.

Table 5. Fluorescence value of coral aggregate concrete

| Sample | 0d  | 2d  | 4d  | 6d  | 8d  | 10d | 12d  |
|--------|-----|-----|-----|-----|-----|-----|------|
| B1     | 0   | 680 | 3392| 4880| 5670| 6371| 6971 |
| B2     | 0   | 424 | 1223| 4073| 4587| 5504| 6249 |
| B3     | 0   | 365 | 1139| 3216| 3661| 4392| 4903 |
| B4     | 0   | 397 | 1560| 1974| 3841| 4275| 5535 |
| B5     | 0   | 335 | 1481| 1756| 2095| 3083| 3421 |
Table 6 Figure 6 test results show that the maximum fluorescence value of concrete surface decreases with the improvement of coating strength grade of mortar for coral aggregate concrete. Compared with C30 coral aggregate concrete without hydrophobic agent, the maximum fluorescence value of M50 mortar coating without hydrophobic agent decreases 8.5%, that value of M100 mortar coating that without hydrophobic agent decreased 23.4%. Compared with C30 coral aggregate concrete without hydrophobic agent, the maximum fluorescence value of M50 mortar Coating decreased by 34.7% with 1% GW, 56.8% with 6% HF, 40.6% with 1% GW and 75.4% with 6% HF. In contrast, when M100 mortar coating with 6% hydrophobic HF is used, the maximum fluorescence value of C30 coral aggregate concrete decreases the most.

Table 6. Fluorescence value of mortar coating

| Sample | 0d  | 2d  | 4d  | 6d  | 8d  | 10d | 12d |
|--------|-----|-----|-----|-----|-----|-----|-----|
| M50    | 0   | 565 | 3269| 4721| 5380| 5938| 6379|
| M50G   | 0   | 172 | 633 | 3374| 3805| 4244| 4553|
| M50H   | 0   | 106 | 549 | 1917| 2379| 2694| 3013|
| M100   | 0   | 295 | 1374| 1784| 3642| 4069| 5343|
| M100G  | 0   | 131 | 970 | 1275| 3059| 3515| 4139|
| M100H  | 0   | 62  | 891 | 1057| 1313| 1523| 1712|

Figure 6. Fluorescence value of mortar coating

The higher the number of cyanobacteria was, the higher the fluorescence value was, and the higher the density and intensity of the imaging under the chlorophyll fluorescence apparatus. It can be seen from the thermal imaging picture corresponding to the maximum fluorescence value of mix proportion B1, B5, M50H and M100H in Figure 7 that with the increase of the maximum fluorescence value, the density and intensity of the fluorescent thermal imaging increase, and the order of the density and intensity of the fluorescent thermal imaging is B1>B5>M50H>M100H. Compared with C30 coral aggregate concrete, M50 mortar and M100 mortar have higher strength grade, denser cement stone
structure, lower water absorption, and less amount of water solution with Chlorella spores attached to the mortar surface. In addition, hydrophobic materials can improve the contact angle between water and mortar surface, making the mortar have certain "self-cleaning" characteristics, further reducing the adhesion of cyanobacteria bracts on the mortar surface, at the same time, the decrease of water absorption of mortar after adding hydrophobic materials also reduces the number of water solution adhesion on the mortar surface and finally deteriorate the "water environment" required for cyanobacteria growth, cyanobacteria Growth was inhibited. [13-15].

Figure 7. Fluorescence thermal imaging of B1/B5/M50H and M100H

4. Conclusions
(1) The mixture of GW hydrophobic agent can improve the fluidity of mortar and the slump of concrete. The mixture of HF hydrophobic agent can reduce the slump of concrete and the fluidity of mortar, but the increase and decrease are not significant.
(2) The addition of GW hydrophobic agent and HF hydrophobic agent will increase the 28d compressive strength of mortar and 28d compressive strength of concrete, but the effect of strength enhancement is not obvious.
(3) The maximum surface fluorescence value of C30 coral aggregate concrete can be reduced by using different strength mortar coating, adding GW hydrophobic agent and HF hydrophobic agent.
(4) Compared with the C30 coral aggregate concrete without hydrophobic agent, the maximum fluorescence value can be reduced by 75.4%.
(5) The inhibition effect of M50 mortar, M100 mortar and hydrophobic agent on the growth of cyanobacteria on the surface of concrete (mortar) may be related to the improvement of the contact environment between concrete (mortar) surface and water, and the specific reasons need further study.

5. References
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