Study on mechanical properties of basalt fiber reinforced coral concrete under loading

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Abstract. Basalt fiber and cement are easy to disperse concrete and mortar, so basalt fiber reinforced concrete plays the role of reinforcement, crack prevention and crack resistance. The basalt fiber has good ductility and corrosion resistance, which can replace the traditional concrete and is widely used in construction engineering. In order to improve the strength of coral concrete in marine engineering, the compressive strength and creep properties of coral concrete mixed with basalt fiber were tested, and the creep prediction model suitable for coral concrete was established. The experimental results show that the effect of basalt fiber on the compressive strength of reinforced concrete is not significant; The creep behavior of basalt fiber reinforced coral concrete is higher than that of ordinary concrete; By modifying the existing creep model, a creep prediction model suitable for coral concrete is established. These experimental results can provide a reference for the design of coral concrete structures in ocean engineering.

1. Introduction
Concrete is a kind of brittle material, which has the defects of low tensile strength and low tensile strain limit. The existing literature shows that adding fiber to concrete is a common means to improve its tensile strength and brittleness. Fiber can inhibit the generation and development of internal cracks in concrete, improve the strength and ductility of concrete. Therefore, adding fiber to concrete is an effective method to improve its basic mechanical properties[1-4].

Basalt fiber, as a kind of inorganic fiber, has good aging resistance compared with organic polypropylene fiber and polyacrylonitrile fiber. Its application in concrete can improve the cohesion and stability of concrete; It improves the impact resistance of concrete, reduces its brittleness, improves the impermeability, freeze-thaw cycle resistance and shrinkage resistance of concrete[5-7]. Therefore, this paper studies the changes of compressive strength and compressive creep properties of coral concrete mixed with basalt fiber, and establishes a creep prediction model suitable for coral concrete.

2. Materials and Methods
The specimens are made of C30 concrete with P·O 42.5 grade produced by Helin cement plant; Coarse aggregate: 5 ~ 16mm continuous graded coral from the South China Sea; Fine aggregate: coral sand with fineness modulus of 2.4 ~ 2.8, belonging to medium sand; According to the existing relevant research and experimental results, the compressive strength and compressive creep performance of coral concrete with 1 kg / m³, 2 kg / m³ and 3 kg / m³ Basalt Fiber (BF) were determined, and compared with ordinary coral concrete without fiber (blank group). The basic parameters and specific mix proportion of basalt fiber are as follows Table 1:
### Table 1 Basic parameters of basalt fiber

| Type          | Elongation at break /% | Tensile strength /MPa | Elastic modulus /GPa | Diameter /μm |
|---------------|------------------------|------------------------|----------------------|--------------|
| Basalt Fiber  | 3.1                    | 2063                   | 56                   | 13           |

### Table 2 Mix proportion of coral concrete with basalt fiber

| Number | Cement (kg/m³) | Coral reef (kg/m³) | Coral sand (kg/m³) | Seawater (kg/m³) | Fiber content (kg/m³) | Water reducing agent (kg/m³) |
|--------|---------------|-------------------|-------------------|-----------------|----------------------|-----------------------------|
| CK     | 557           | 749               | 749               | 195             | 0                    | 4                           |
| BF1    | 557           | 749               | 749               | 195             | 1                    | 4                           |
| BF2    | 557           | 749               | 749               | 195             | 2                    | 4                           |
| BF3    | 557           | 749               | 749               | 195             | 3                    | 4                           |

The compressive strength test specimen is 150 mm × 150mm × 150 mm cube, according to the mix proportion in Table 2, the concrete test block is poured and put into the standard curing room for curing. According to the standard GB / T 50081-2009, the compressive strength of the test block of each group is measured and the average value is calculated.

The compressive creep test of coral concrete is carried out by using 100 mm × 100mm × 300 mm prism. Compression creep test: the creep measuring device is embedded in advance. After demoulding the specimen, the compression creep value is tested after the specimen is cured to the age under standard curing conditions. The test method refers to GB / T 50082-2009 standard for test methods of long term performance and durability of ordinary concrete.

### 3. Results & Discussion

#### 3.1. Compressive strength test of coral concrete with basalt fiber

The results of compressive strength of coral concrete with basalt fiber at different times are shown in Table 3. The compressive strength of basalt fiber coral concrete specimens with different contents and ages of 3, 7, 14 and 28 days are analyzed, as shown in Figure 1. The compressive strength of coral concrete with basalt fiber increases with age, and its early strength develops rapidly. It can reach 80% of its 28d compressive strength in 3 days, but the growth rate of strength gradually becomes gentle after 7 days. Basalt fiber has good chemical stability and thermal stability, and does not participate in or change the hydration reaction of cement. Therefore, the strength development law of fiber coral concrete is similar to that of ordinary coral concrete. The early strength growth rate is fast, and the later growth rate is slow. The effect of basalt fiber on the compressive strength of concrete is not significant.

| Number | Compressive strength /MPa |
|--------|---------------------------|
|        | 3d | 7d | 14d | 28d |
| CK     | 21.5 | 24.8 | 29.2 | 31.4 |
| BF1    | 22.8 | 26.7 | 28.6 | 29.1 |
| BF2    | 20.9 | 25.2 | 27.1 | 28.2 |
| BF3    | 21.9 | 24.0 | 26.3 | 28.7 |
3.2. Compressive creep behavior model of coral concrete with basalt fiber

Because the ability of coral coarse aggregate to restrain the shrinkage deformation of hydrated cement paste is obviously weaker than that of ordinary gravel, and the influence of its low elastic modulus, the instantaneous deformation and final creep of coral concrete are greater than that of ordinary concrete during creep test.

The ACI-209 model proposed by ACI-209 Committee of American Concrete Association in 1982 can better simulate the creep of ordinary concrete. There is a large deviation in the simulation of compressive creep of coral concrete mixed with basalt fiber by using this model directly. It is found that R² ranges from 0.34 to 0.87. The model is a hyperbolic power function of the product of creep coefficient and time function, as shown in equation (1).

\[
\varphi(t, \tau) = 2.35 \gamma_a \gamma_s \gamma_h \gamma_f \gamma_{Rh} \frac{(t - \tau)^{0.6}}{10 + (t - \tau)^{0.6}}
\]  

Where:
- \( \gamma_a \) - Air content correction factor,
- \( \gamma_s \) - Slump correction factor,
- \( \gamma_h \) - Correction factor of specimen size,
- \( \gamma_f \) - Fine aggregate content correction factor,
- \( \gamma_{la} \) - Correction factor of concrete loading age,
- \( \gamma_{Rh} \) - Correction factor of environmental relative humidity,
- \( t \) - Calculated age,
- \( \tau \) - Loading age.

Compared with other models, the simulation value of ACI-209 model has higher fitting degree with the actual creep data of basalt fiber reinforced coral concrete in this paper, and the two parameters of coral aggregate and fiber content are the influencing factors of creep of basalt fiber reinforced coral concrete, This model can better reflect the compression creep state of coral concrete with basalt fiber. The specific expression is shown in equation (2).

\[
\varphi(t, \tau) = K \gamma_{ag} \gamma_{fb} 2.35 \gamma_a \gamma_s \gamma_h \gamma_f \gamma_{la} \gamma_{Rh} \frac{(t - \tau)^{0.6}}{10 + (t - \tau)^{0.6}}
\]  

Where:
- \( K \) - Basic correction coefficient of coral concrete, with the value of 0.9068,
- \( \gamma_{ag} \) - correction coefficient of coral aggregate substitution rate,
- \( \gamma_{fb} \) - correction coefficient of basalt fiber content.

Comparing the test results of ordinary concrete and coral concrete with the model calculation results, taking the replacement rate of coral aggregate as a parameter, through multivariate nonlinear fitting, the expression of the correction coefficient \( \gamma_{ag} \) is obtained.

\[
\gamma_{ag} = 0.5018e^{0.506a}
\]
Where: $a$ - replacement rate of coral aggregate

Comparing the test results and model calculation results of each group of coral concrete mixed with basalt fiber, taking the fiber content as a parameter, the expression of correction coefficient $\gamma_{fb}$ is obtained.

\[
\gamma_{fb} = -0.0024b + 1.0010
\]

Where: $b$ - volume content of fiber.

Using the modified model, it is found that the R2 of each group of coral concrete with basalt fiber has been improved to a certain extent. Finally, the creep prediction model of coral concrete with different basalt fiber content is obtained. Through calculation, it is found that the fitting effect of the model fitting value and the test result is good, and the linear regression judgment coefficient R2 is above 0.95.

4. Conclusion

Fiber reinforced concrete can make up for the shortcomings of traditional concrete, improve the performance of traditional concrete, so it will be more and more widely used in the field of construction engineering, and the mechanical properties of basalt fiber reinforced concrete under load has become a hot issue. It is found that the early strength of coral concrete with basalt fiber increases rapidly, reaching 80% of its 28d compressive strength in 7d, and the strength growth rate tends to be flat after 7d; ACI-209 model can simulate the creep of coral concrete mixed with basalt fiber. The ACI-209 model modified by coral aggregate replacement rate and basalt fiber content has high fitting degree and good prediction effect for creep prediction of coral concrete mixed with basalt fiber. But in practical engineering, in addition to load, coral concrete often faces the problem of chloride ion erosion. Therefore, the future research work should focus on the mechanical properties of coral concrete structure with multi factor coupling, which is closer to the engineering practice and more valuable.

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