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STUDY ON ANTI-CRACKING PERFORMANCE EVALUATION METHOD OF STEEL FIBER REINFORCED CERAMSITE CONCRETE (SFRCC) BASED ON PARTLY-RESTRAINED SHRINKAGE RING

Zhang Yi-fan

College of Environment and Civil Engineering,Chengdu University of Technology,Chengdu 610059, China

ABSTRACT

In the study of crack resistance of steel fiber reinforced concrete in steel fiber on concrete deformation ability and prevent the Angle of the micro cracks, and the lack of overall evaluation on the performance of steel fiber reinforced concrete crack. By tinder barrier-free restrain some experimental research on steel fiber ceramsite concrete shrinkage ring crack resistance, and use the test results within the definition of steel ring strain from expansion to contraction cut-off age for early and late ages, and the ages of the cut-off point for the early and the late steel fiber ceramsite concrete anti-cracking performance evaluation. The results show that the anti-cracking properties of the steel fiber ceramic concrete are improved with the increase of steel fiber content.

KEYWORDS

Alkali slag cement, No diaphragm shrinkage ring, Concrete structure, Evaluation of crack resistance

INTRODUCTION

The shrinkage cracking of high performance concrete is one of the problems frequently encountered in engineering. Shrinkage ring test, based on some constraints can be used to study regeneration powder admixture of concrete shrinkage cracking tendency, the influence of the research shows that some reasonable constraint shrinkage ring test to evaluate the ability of resisting shrinkage cracking of concrete [1]. Different scholars for related research was conducted on the crack resistance of steel fiber reinforced concrete, steel fiber can prevent the expansion of the internal micro cracks of concrete added, and increase the tensile strength of concrete, and then against the improvement of the performance of the crack [2-3]. In this paper, the anti-cracking performance of the regenerated aggregate concrete with different presenting degree can be evaluated by partial constraint shrinkage ring test [4]. Literature [5] proposed a quick evaluation method for the anti-crack performance of lightweight aggregate concrete with the restraint shrinkage ring.

This paper proposes a more simple part with partition with constraint shrinkage ring crack resistance of concrete fast evaluation method, and evaluation by the method caused by autogenous shrinkage of steel fiber reinforced ceramists concrete anti-cracking performance of (SFRCC).

TEST

1. Raw Materials and Proportion

1: Cement: use Sichuan refined stone brand 42.5R regular Portland cement, apparent density 3050kg/m^3, 28day compressive strength of 45 MPa.

2: Steel fiber: shear wave shape steel fiber produced by Zhejiang Haining Bonn metal products co., LTD.

3: Ceramic granule: adopt the ceramic pellet of Yichang, Yichang, Hubei.

4: Fine aggregate: the Kawjiang river sand with a fineness modulus of 2.5, the stacking density of 1481 kg/m^3, the apparent density of 2590 kg/m^3.

5: Water: use tap water in Chengdu area.

6: Water reducing agent: using twin-js polycarboxylic acid water reducing agent produced by Sichuan institute of building science, the water reducing rate is 15~18%.In this experiment, the ceramists presetting 1h was used in this experiment, and the design of the variation parameters with the steel fiber content was shown in Table 1. Test condition is based on air temperature is 25 ℃, humidity is 86%.

Tab. 1 - Concrete mixture ratio [kg/m3]

Component / Numbering	Cement（kg/m^3)	Sand（kg/m^3)	ceramsite（kg/m^3)	Water（kg/m^3)	Water reducing agent（kg/m^3)	Steel fiber volume rate Vf（%）
SF00	476	698	583	167	8	0
SF05	476	698	583	167	8	0.5
SF10	476	698	583	167	8	1
SF20	476	698	583	167	8	2

2. Test Method

2.1 Partial constraint shrinkage ring test device

Restrain some shrinkage ring test, some constraint shrinkage ring device is in the literature [5-6] research concrete crack resistance device, which on the basis of the original device is equipped with diaphragm in the concrete ring, this experiment adopts some constraints, remove the diaphragm shrinkage ring device. The purpose of the partition plate is to produce stress concentration and accelerate the appearance of concrete ring cracks in the partition. But due to the crack evaluation index (area method) to evaluate, the cracking of do not need to be visible to the naked eye[5], surrounded by a certain age crack coefficient is included in the area of internal micro cracks of concrete information [9].This not only simplifies the device, but also can meet the requirements of rapid evaluation. The improved part constraint shrinkage ring device schematic diagram is shown in Figure 1, strain gauge sets, steel ring inside height 1/2, 1 (point 1) strain gauge set with 2 (point 2) strain gauge is just right across the street at 180 °. The specific dimensions of the device are shown in Table 2.

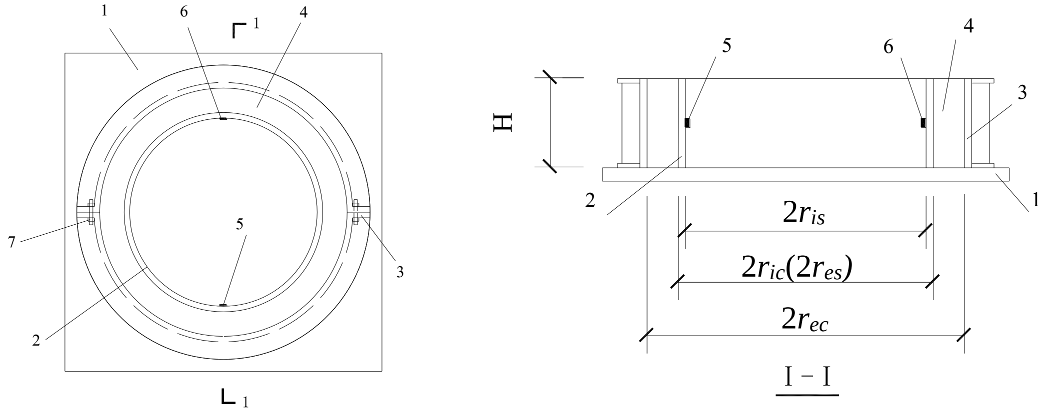

Fig.1 - No partition device schematic part shrinkage

Injection: 1- The tablet; 2- The steel ring; 3- The steel ring; 4- Concrete ring; 5- Strain gauge 1; 6- Strain gauge 2; 7- Bolts of fixed outer ring; $2r_{ec}$- The outer diameter of the concrete ring; $2r_{ic}$ ($2r_{es}$)- Outer diameter of the inner diameter or inner ring of a concrete ring; $2r_{is}$ - Inner diameter of inner steel ring; H- The height of a concrete ring or steel ring.

Tab. 2 - The size of the ring test device is constrained by the constraint of the partition [mm]

$2r_{ec}$	$2r_{ic}$ ($2r_{es}$)	$2r_{is}$	H
395	315	299	100

2.2 The Test Results

In partial constraint shrinkage ring test, the development of the inner steel ring strain (epsilon st) (the average of measurement point 1 and point 2) is shown in Figure 2.

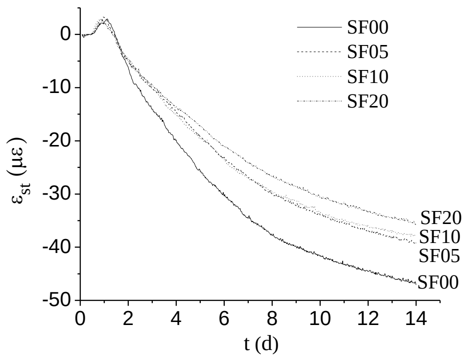

Fig.2 - Internal steel ring strain

3. Basic Mechanical Properties Test

Basic mechanical properties of concrete test according to the specification of ordinary concrete mechanics performance test method standard (GB50081-2002-T) [7], measurement of different steel fiber content of ceramsite concrete 1d., 2d, 3d, 5d, 7d and 14d and 28d compressive strength, splitting tensile strength. According to the standard of normal concrete long-term performance and endurance performance test method (GB/T 50082-2009) [8],the dt-15 moving-mode meter was used to measure the elastic modulus of sfr1d, 2d, 3d, 5d, 7d, 14d and 28d of SFRCC. The test results are shown in Tables 3-5.

Tab. 3 - Compressive strength [MPa]

Group number / Age	SF00	SF05	SF10	SF20
1d	15.19	20.15	15.46	16.91
2d	22.01	26.39	23.15	24.52
3d	25.77	29.63	27.50	28.74
5d	29.90	33.07	32.37	33.43
7d	32.38	35.07	35.31	36.24
14d	36.58	38.38	40.39	41.04
28d	39.81	40.86	44.32	44.74

Tab. 4 - Splitting tensile strength [MPa]

Group number / Age	SF00	SF05	SF10	SF20
1d	2.06	2.43	3.25	4.45
2d	2.33	2.75	3.54	4.67
3d	2.46	2.91	3.68	4.78
5d	2.59	3.06	3.81	4.87
7d	2.66	3.15	3.89	4.93
14d	2.77	3.28	4.01	5.01
28d	2.85	3.38	4.09	5.07

Tab. 5 - Dynamic modulus of elasticity [GPa]

Group number / Age	SF00	SF05	SF10	SF20
1d	21.64	21.19	22.87	23.04
2d	23.77	23.53	25.05	25.19
3d	24.77	24.63	26.06	26.18
5d	25.74	25.72	27.07	27.17
7d	26.28	26.32	27.62	27.71
14d	27.13	27.28	28.50	28.57
28d	27.74	27.96	29.12	29.18

According to European standard [9], the use of 1 d, 28 d compressive strength, splitting tensile strength and elastic modulus formula of fitting, calculate the splitting tensile strength of each age, other smaller error between the theoretical value and the measured values is calculated [10].The development of the tensile strength during the period of 14d of the ceramic concrete with different steel fiber content is shown in Figure 3.

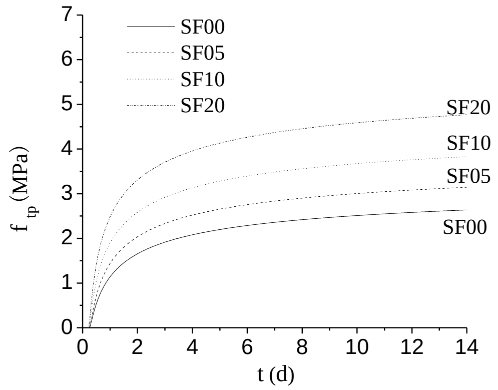

Fig. 3 - Splitting tensile strength at different ages

4. Evaluation of Crack Resistance

In the partial constraint shrinkage ring test, the equilibrium relation between the inner ring and the concrete ring is obtained, and the cyclic tension stress can be calculated by Equation (1) [5].

$$\sigma_c = \frac{h_{st}}{h_c}\sigma_s = \frac{E_{st}h_{st}}{h_c}\varepsilon_{st}(t) \qquad (1)$$

In this paper, $\sigma_c(t)$ is the cyclic tensile stress of the concrete ring during the phase of the shrinkage ring in the circumferential ring test is restricted; $\sigma_s(t)$ is the circumferential stress of the inner steel ring at the age of t; E_{st} is the elastic modulus of inner steel ring (195GPa); h_{st} is the inner steel ring thickness (12mm); h_c is the thickness of the concrete ring (40mm),that is $(r_{ec}-r_{ic})$ or $(r_{ec}-r_{es})$.

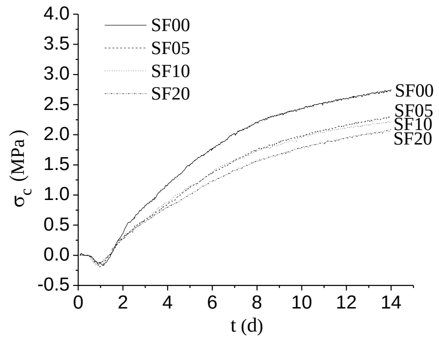

Fig. 4 - Relationship between concrete ring stress and age

ANALYSIS AND DISCUSSION

1. Evaluation Index of Crack Resistance

This paper presents a quick evaluation method for the crack resistance of concrete, There are two concepts of cracking coefficient $\zeta_t(t)$ and anti-crack evaluation index $A_{cr}(t)$ [5]. The cracking coefficient $\zeta_t(t)$ is the cyclic stress of concrete at the age of age with the tensile strength of concrete is corresponding $f_t(t)$ the ratio of tensile strength instead of the tensile strength is used in this paper, as shown in formula (2).

$$\zeta_t(t)=\frac{\sigma_c(t)}{f_t(t)} \qquad (2)$$

Anti-crack evaluation index $A_{cr}(t)$ is the concrete cracking coefficient $\zeta_t(t)$ the integral of phase t, As shown in formula (3).

$$A_{cr}(t)=\int_0^t \frac{\sigma_c(t)}{f_t(t)}dt=\int_0^t \zeta_t(t)dt \qquad (3)$$

The cracking coefficient of concrete $\zeta_t(t)$ with the diagram of relationship diagram of age t is shown in Figure 5 (In this case, the decrease of the coefficient of cracking coefficient due to temperature change is not considered)

According to formula (2), the cracking coefficient of SFRC can be obtained with the development rule of the age. As shown in Figure 5, the anti-crack evaluation index is obtained by formula (3) as shown in Table 6.

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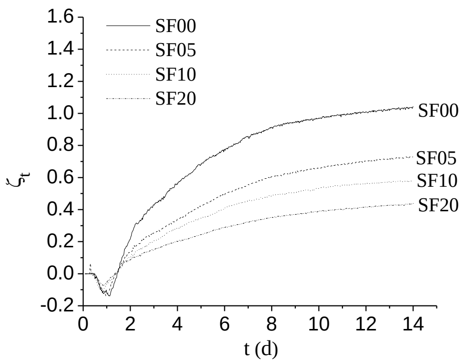


Fig. 5 - Relationship between cracking coefficient and age

Tab. 6 - Crack resistance evaluation index [d]

Group number	SF00	SF05	SF10	SF20
Early phase	-0.081	-0.063	-0.052	-0.034
Lately phase	9.88	6.56	5.30	3.87
Total	9.80	6.49	5.24	3.83

2. Anti-cracking performance evaluation method

Based on the literature [5] based on the anti-crack evaluation method based on partial constraint shrinkage ring test, the anti-cracking performance of SFRCC can be evaluated according to the following methods:

1. The anti-cracking performance of SFRC is better than that of SFRCC in the descending segment;

2. In the case of SFRCC for the cracking coefficient, the size of the anti-crack evaluation index $A_{cr}(14)$ of 14d phase is compared, and the larger the $A_{cr}(14)$ is, the better the anti-crack performance of the SFRCC;

3. For the cracking coefficient, the SFRCC is not reduced, and the size of the anti-crack evaluation indicator $A_{cr}(14)$ in 14d phase is compared, and the smaller $A_{cr}(14)$ is, the better the anti-crack performance of SFRCC;

The Figure 5 shows that SF00 SF05, SF10, cracking coefficient of SF20 group were only rise period, the Table 5 shows that SF20 $A_{cr}(14)$ minimally, followed by SF10, then SF05, SF00 group of $A_{cr}(14)$ is the largest, so the crack resistance order from good to bad SF20 > SF10 > SF05 > SF00.Therefore, the anti-cracking performance of SFRC increases with the increase of steel fiber content.This conclusion is confirmed by literature[4-5], indicating the correctness of the evaluation method.

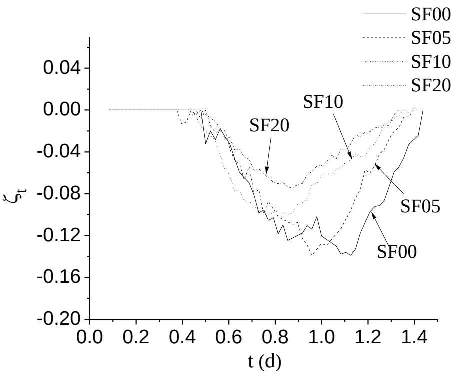
3. Early and late crack resistance

The heat of the cement hydration reaction causes the concrete ring temperature to rise, the concrete ring heat transfers to the inner steel ring, so that the inner steel ring temperature also rises, then the inner steel ring expands.After the expansion of the concrete ring due to shrinkage and increase of elastic modulus, the concrete ring is strengthened by the contraction of the inner steel ring, resulting in the inner steel ring from expansion to contraction.For different types of concrete, the change of heat, elastic modulus and shrinkage of the water reaction are different, which can lead to different time points of internal steel ring strain from expansion to contraction.This time point is defined as the early and later boundary point of concrete, and the early and later boundary points of different steel fiber content are shown in Table 6.As can be seen from Table 7, the quantity of steel fiber has little effect on the age of dividing point.

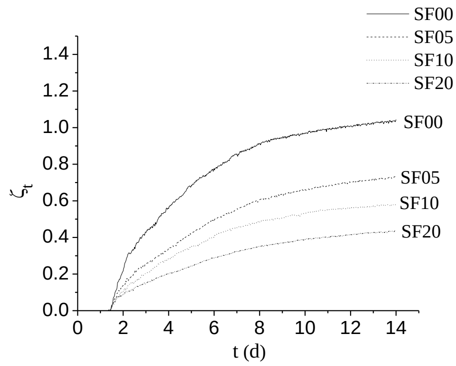
Tab. 7 - The age of demarcation between early and late [d]

SF00	SF05	SF10	SF20
1.44	1.40	1.42	1.33

Put some constraints in Figure 5 the cracking coefficient of shrinkage ring test according to the early and late departure, get SFRCC law of development of early and late cracking coefficient along with age as shown in Figure 6, the corresponding crack evaluation index calculation results are shown in Table 6.



(a) Early period



(b)Later period

Fig. 6 - Relationship between cracking coefficient and age at early and late stages

The Figure 6, Table 6 shows that in some parts of the constraint shrinkage ring test, the early cracking of SFRCC coefficient $\zeta_t(t)$ and anti-crack evaluation index $A_{cr}(t)$ is negative, its value is less than the total 1%, negligible, so can be directly used in the late of anti-crack evaluation index to evaluate the anti-cracking performance of concrete.Late evaluation index with ceramsite concrete crack resistance of steel fiber content increase and decrease, so the late SFRCC crack resistance along with the increase of steel fiber content increased, the consistent with SFRCC overall cracking index evaluation result.

CONCLUSIONS

(1) The constraint shrinkage ring experiment, exist in the steel ring strain from expansion to shrink, the moment the ages of the corresponding defined as the cut-off point of early and late ages, steel fiber content of steel fiber ceramsite concrete cut-off (SFRCC) age.

(2) Based on the concept of partial constraint shrinkage loop test and cracking coefficient $\zeta_t(t)$ and cracking evaluation index $A_{cr}(t)$, the evaluation method of anti-cracking performance of SFRCC is given.

① The anti-cracking performance of SFRCC is better than that of SFRCC in the descending segment;

② The crack coefficient appears to be in the lower part of SFRCC, and the size of the anti-crack evaluation index $A_{cr}(14)$ in 14d phase is compared, and the larger the $A_{cr}(14)$ is, the better the anti-crack performance of the SFRCC;

③ For the cracking coefficient of SFRCC, the size of the index $A_{cr}(14)$ of the anti-crack evaluation index of 14d phase was compared, and the $A_{cr}(14)$ was smaller, the better anti-crack performance of SFRCC is.

(3) Early anti-crack evaluation indexes are small and can be ignored, and the anti-cracking performance of SFRCC can be correctly evaluated by using the anti-crack evaluation index and the total anti-crack evaluation index.

(4) The anti-cracking performance of SFRCC increases with the increase of steel fiber content.

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