第V部門

2024年9月5日(木) 9:30 ~ 10:50 C306(川内北キャンパス講義棟Ｃ棟)

短繊維補強コンクリート（材料）(1)

座長：岩下 健太郎（名城大学）

10:00 ~ 10:10

[V-380] Tensile Characteristics of Fiber-Reinforced Cementitious Composite with Recycled Carbon Fiber

*金久保 利之[1]、李 思聡[1]、張 航[1] (1. 筑波大学)

キーワード：FRCC、リサイクル炭素繊維、一軸引張試験、架橋則、断面解析

本研究では，溶媒法によるリサイクル炭素繊維を用いた繊維補強セメント複合材料（FRCC）について，繊維の架橋性能を明らかにするために，FRCCの一軸引張試験を行った．架橋則の評価を通して，引張荷重－ひび割れ幅関係を与えるための単繊維の架橋モデルを提案した．計算された架橋則を用いた断面解析の結果による最大曲げモーメントは，既存の同材料の曲げ試験で得られた値とよい一致を見た．

Tensile Characteristics of Fiber-Reinforced Cementitious Composite with Recycled Carbon Fiber

筑波大学　正会員　○Toshiyuki Kanakubo
筑波大学　学生会員　Sicong Li
筑波大学　学生会員　Hang Zhang

1. INTRODUCTION

The authors have focused on the usage of recycled carbon fiber as a mixed discrete fiber in fiber-reinforced cementitious composite (FRCC). The fundamental compressive and bending characteristics of FRCC with recycled carbon fiber by the pyrolysis (CF-PY) and solvolysis (CF-SO) method have been investigated in the previous study [1], and FRCC with CF-SO have shown better improvements in bending strength and toughness of FRCC. This study conducts a uniaxial tension test on FRCC with CF-SO to clarify the bridging effect of carbon fiber. An individual fiber bridging model is proposed to express the tensile load versus crack width of FRCC via bridging law calculation.

2. EXPERIMENT OVERVIEW

The mixture proportion of FRCC is shown in Table 1. Recycled carbon fiber by solvolysis method (CF-SO) is used. The length of the fiber is controlled at 10 mm. The fiber volume fraction is set at 0.5%. Table 2 shows the mechanical properties of virgin fiber provided by the manufacturer. The compressive strength and the elastic modulus of FRCC obtained by ϕ100-200 mm cylinder test pieces at the loading age of the uniaxial tension test is 41.9 MPa and 16.2 GPa, respectively.

Fig. 1 shows the dimensions of the uniaxial tension test specimen. The test section is 30 mm long with a cross-sectional area of 5 mm × 5 mm. These dimensions of the test section ensure that the fiber orientation remains consistent, thus eliminating the influence of fiber orientation to directly obtain the fiber bridging model. Though the total of twenty specimens was prepared, seven specimens were damaged and rendered unusable during the demolding process. Thirteen specimens were tested.

Table 1 Mixture proportion

Series	W/B	FA/B	Unite weight (kg/m^3)			
			W	C	FA	S
CF-SO-0.5%	0.39	0.30	380	678	291	484

W: water, C: high early strength Portland cement, FA: fly ash type II, S: silica sand

Table 2 Mechanical properties of fiber

Type	Length (mm)	Diameter (μm)	Tensile strength (MPa)	Elastic modulus (GPa)
CF-SO	10	5	5800	294

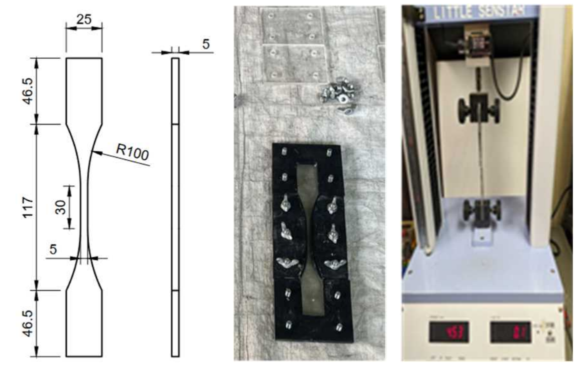

Fig. 1 Uniaxial tension test specimen (unit: mm)


Fig. 2 Specimens after loading

The loading was carried out using an electronic system universal testing machine with a capacity of 200 N (Fig. 1) and a loading speed of 1 mm/min. The tensile load and the head displacement were recorded.

3. TEST RESULTS

Fig. 2 shows the photos of specimens after loading.

Keywords　FRCC, Recycled carbon fiber, Uniaxial tension test, Bridging law, Section analysis
Address　〒305-8573 茨城県つくば市天王台 1-1-1
筑波大学構造エネルギー工学域 TEL 029-853-5045

During the loading process, a crack formed in the central position of the specimens. Most of the fibers were ruptured. The average value of the maximum load is 108.2 N. The tensile strength ranging from 2.32 MPa to 6.64 MPa, and the average tensile strength is 4.32 MPa.

4. FIBER BRIDGING MODEL

The bridging law (tensile stress vs. crack width relationship) is calculated by the summation of forces carried by individual bridging fibers. Since the uniaxial tension test specimens exclude the influence of fiber orientation, the only factor affecting fiber bridging behavior is the embedded length of the individual fibers. The calculated bridging force can be obtained by Eq. (1).

$$P_{bridge} = \sum\nolimits_{l_b \le l_f/2} P(l_b) \qquad (1)$$

Where, P_{bridge}: bridging force, $P(l_b)$: pullout force of individual fiber, l_b: embedded length, l_f: fiber length.

According to the experimental results, the individual fiber bridging model can be obtained reversibly using Eq. (1). Fig. 3 illustrates the individual fiber bridging model, which is the bi-linear model. Based on the average value of the maximum load, P_{bridge} has been determined to be 108.2 N. The crack width at the maximum is determined from the average experimental data and has been measured to be 0.25 mm. The spreadsheet software (Excel) procedure is used to calculate the bridging law. As a result of finding the characteristic points, the maximum tensile load of the individual fiber is determined as 0.0177 N and the corresponding crack width is 0.25 mm as shown in Fig. 3. The calculation result of bridging law is shown in Fig. 4. The load becomes to zero when crack width becomes equal to half of fiber length.

5. SECTION ANALYSIS

Section analysis is conducted to evaluate the adaptability of calculated bridging law of FRCC. The stress-strain model in tension side is derived based on the bridging law depicted in Fig. 4 by bi-linear model, and the data from compression test are used in compression side by the parabolic model. For tension side, stress is obtained by dividing the load by the cross-sectional area, while strain is determined by dividing the crack width from the bridging law by the pure bending length of 100 mm, as

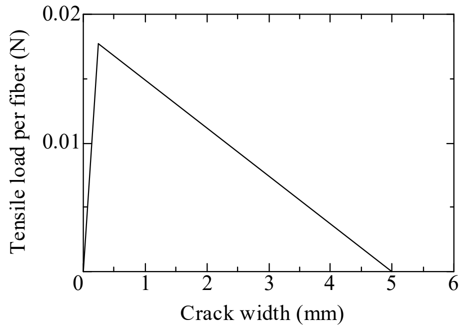

Fig. 3 Individual fiber bridging model

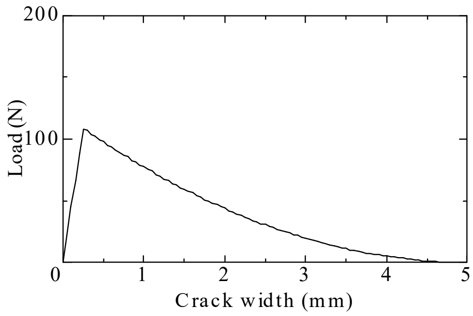

Fig. 4 Calculation result of bridging law

Table 3 Result of section analysis

Series	Maximum moment (kN・m)		Experiment / Analysis
	Experiment	Section analysis	
CF-SO-0.5%	1.638	1.561	0.95

previously reported [2]. Table 3 shows the list of maximum bending moment by experiment [2] and calculated values. The calculated maximum bending moment is 0.95 times the experimental data, showing a close agreement.

6. CONCLUSIONS

1) The bridging law, derived from the uniaxial tension test, serves as the subject for further exploration of the tensile characteristics of FRCC by solvolysis method recycled carbon fiber.
2) The calculated maximum bending moment by section analysis is 0.95 times the experimental data, demonstrating a close agreement.

ACKNOWLEDGEMENTS Recycled carbon fiber was provided by MIRAI KASEI INC.

REFERENCES

[1] Sasaki, H., Li, S., Kanakubo, T., Fabrication of Fiber-Reinforced Cementitious Composite with Recycled Carbon Fiber, JSCE 2023 Annual Meeting, V-751, 2023.
[2] Li, S., Sasaki, H., Kanakubo, T., Bending Characteristics of Fiber-Reinforced Cementitious Composite with Recycled Carbon Fiber, JSCE 2023 Annual Meeting, V-752, 2023.