第V部門

2026年9月2日(水) 10:30 ~ 11:50 | 7号館1階D103（北海学園大学）

短繊維補強コンクリート（材料）2

座長：佐々木 亘（三井住友建設）

11:00 ~ 11:10

[V-43] Shear Behavior of FRCC Beams Reinforced with Steel Bars

*新田 真麻[1]、Negash Shiferaw Helen[1]、金久保 利之[1]、Sivasubramanian Madappa V. R.[2]、Kamalakannan Hamsavathi[2] (1. 筑波大学、2. NIT, Puducherry)

キーワード：繊維補強セメント複合材料、梁、せん断耐力、ポリエステル繊維、ポリビニルアルコール繊維

繊維補強セメント系複合材料（FRCC）は，ひび割れ発生後の挙動，靭性，およびエネルギー吸収性を向上させる．繊維はひび割れを架橋することでせん断性能に影響を及ぼし得る．本研究では，鉄筋で補強されたFRCC梁のせん断挙動を解明するため，4点曲げ載荷を実施した．変動因子は繊維体積混入率，繊維種類である．計測項目は，荷重，載荷点たわみ，引張側補強筋部の載荷点部ひずみである．実験結果より，FRCC試験体のせん断耐力は，繊維を含まない試験体の1.35倍から2.44倍であった．また，FRCC試験体のせん断耐力は，FRCCに使用された繊維の種類によって異なり，2%の繊維径の小さいPVA繊維を含んだ試験体のせん断耐力が最も大きかった．

Shear Behavior of FRCC Beams Reinforced with Steel Bars

筑波大学　学生会員　○新田真麻
筑波大学　正会員　金久保利之
筑波大学　学生会員　Shiferaw Helen Negash
NIT, Puducherry　非会員　Madappa V. R. Sivasubramanian
NIT, Puducherry　非会員　Hamsavathi Kamalakannan

1. INTRODUCTION

Fiber-reinforced cementitious composites (FRCCs) integrate a cementitious matrix with discrete short fibers to improve post-cracking behavior, toughness, and energy absorption. By bridging cracks, fibers enhance tensile and flexural response and alter crack patterns and stiffness properties that can influence shear performance, a critical and brittle failure mode in reinforced concrete members.

In this study, a four-point bending test is conducted to understand the shear behavior of FRCC beams reinforced with steel bars.

2. EXPERIMENT OVERVIEW

2.1 Beam specimen

The test specimen ID, used steel type, fiber type, and volume fraction are listed in Table 1. The specimen ID is a combination of main bar type, fiber type, fiber diameter, and fiber volume fraction. The specimen ID “MT” is given for the specimens without fiber. Fig. 1 shows the specimen geometry and cross-section. The beam dimensions are 160 × 230 × 1500 mm, and it is reinforced with two D13 bars on the compression side and four on the tension side. Two types of fibers are used in the FRCC: polyester (PES) fibers and polyvinyl alcohol (PVA) fibers. PES fibers had a length of 12 mm and a diameter of 30 μm, and two types of PVA fiber dimensions are used: one with a length of 6 mm and a diameter of 27 μm, and another with a length of 12 mm and a diameter of 100 μm. Steel couplers filled with expansion agent were used as the anchorage at both ends. Fig. 2 shows the types of fibers used, and Table 2 lists the mechanical properties of the fibers. Table 3 shows the FRCC mix proportion and the compressive properties by the φ100 mm × 200 mm cylindrical test pieces. The yield strength and elastic modulus of main bar was 568 MPa and 191 GPa, respectively.

Table 1 List of specimens

ID	Main bar	Fiber type	Fiber volume fraction
S/MT	D13（SD490）	—	—
S/PES030-1		PES	1%
S/PVA027-1		PVA	1%
S/PVA027-2			2%
S/PVA100-1			1%
S/PVA100-2			2%

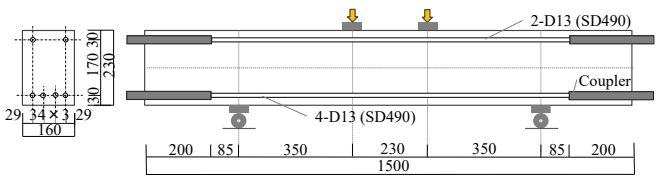

Fig.1 Specimen geometry

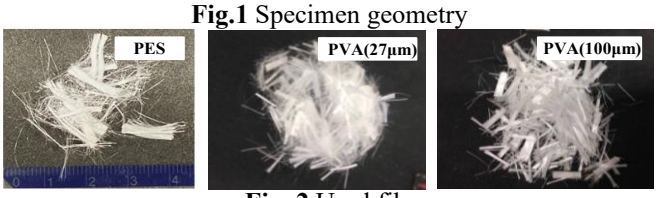

Fig. 2 Used fiber

Table 2 Mechanical properties of fibers

Fiber type	Diameter (μm)	Length (mm)	Tensile strength (MPa)	Elastic modulus (GPa)
PES	30	12	460	5
PVA	27	6	1800	45
	100	12	1200	28

Table 3 FRCC mix proportion and compressive properties

ID	Unit weight（kg/m^3）				σ_B	Ec
	W	C	S	FA	(MPa)	(GPa)
S/MT	380	678	484	291	45.9	18.3
S/PES030-1					42.3	17.7
S/PVA027-1					44.7	17.3
S/PVA027-2					44.5	15.0
S/PVA100-1					45.9	16.1
S/PVA100-2					43.9	15.3

W : Water, C : Cement, S : Sand,
FA : Fly ash, σ_B : Compressive strength, Ec : Elastic modulus

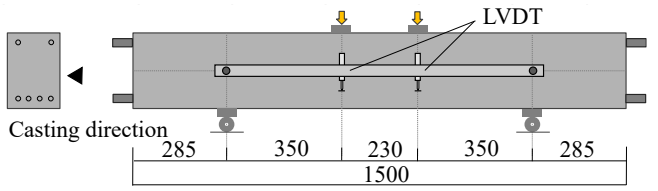

Fig.3 Loading and measurement setup

Keyword: FRCC, Beam, Shear capacity, Polyester fiber, PVA fiber
Contact address: University of Tsukuba, 1-1-1 Tennodai, Tsukuba, Ibaraki, 305-8573 TEL 029-853-5045

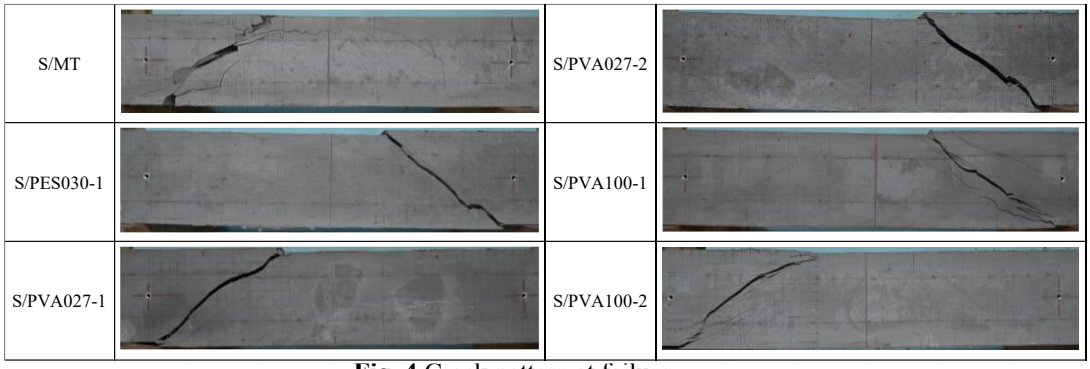

Fig. 4 Crack pattern at failure

2.2 Loading and measurement

The loading was performed using a 2000 kN compression testing machine with a four-point bending configuration. The assumed failure mode was shear failure. The measured items were applied load, load point deflection using two displacement transducers, and strain at four points on the tension bars at the loading section. Fig. 3 shows the loading and measurement setup.

3. EXPERIMENTAL RESULTS

3.1 Failure progress

Table 4 shows the shear force and deflection at the maximum load, and failure mode. Fig. 4 shows the photos of the specimens after loading. In all specimens except S/PVA027-2, shear cracks propagated, leading to a decrease in applied load. In the S/PVA027-2 specimen, the main bar yielded first, and after the load increased slightly, shear cracks propagated, resulting in a decrease in applied load. As shown in Fig. 4, in all specimens, shear cracks propagated diagonally connecting the loading point and the support point.

3.2 Load-deflection relationship

Fig. 5 shows the load-deflection relationship. The maximum shear force of the FRCC specimens was 1.35 to 2.44 times greater than that of the MT specimens without fiber. Since the tensile strength and elastic modulus of PES fibers are lower than those of PVA fibers, the maximum shear force of the S/PES030-1 specimens was smaller than that of the S/PVA027-1 and S/PVA100-1 specimens. When comparing FRCC specimens with the same type of fiber, the maximum shear force increased with increasing fiber volume fraction. The post-cracking stiffness of the S/PVA027-1 and S/PVA027-2 specimens was greater than that of the other specimens, which is considered to be due to the use of fibers with smaller diameters. For the same fiber volume fraction, the surface area of fibers increases as the diameter decreases, leading to enhanced bond strength between the matrix and fibers and improved bridging performance. Although no significant difference in maximum shear force was observed between the S/PVA100-1 and S/PVA100-2 specimens, the specimen with a fiber volume fraction of 2% exhibited a more gradual post-peak behavior. This is considered to be due to the suppression of brittle failure as a result of the increased fiber fraction.

Table 4 Test result

ID	At maximum load		Failure mode
	Q_{max} (kN)	δ_{max} (mm)	
S/MT	70.3	3.37	Shear
S/PES030-1	95.0	2.72	Shear
S/PVA027-1	109.9	2.91	Shear
S/PVA027-2	171.3	6.11	Yield-Shear
S/PVA100-1	121.3	4.70	Shear
S/PVA100-2	125.0	4.21	Shear

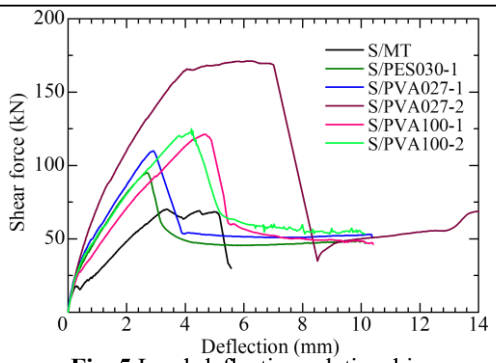

Fig. 5 Load-deflection relationship

4. CONCLUSIONS

1.The shear capacity of the FRCC specimens was 1.35 to 2.44 times greater than that of the specimens without fiber.

2.The shear capacity of the FRCC specimens varied depending on the type of fiber used in the FRCC. The shear capacity of the specimen with 2% finer PVA fibers was highest.

Acknowledgment

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