第V部門

2026年9月4日(金) 16:20 ~ 17:40 | 7号館4階D40（北海学園大学）

耐震補強4／連続繊維補強コンクリート

座長：内藤 英樹（東北大学）

17:00 ~ 17:10

[V-814] Shear Behavior of FRCC Beams Reinforced with AFRP Bars

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キーワード：FRCC、PVA fiber、AFRP bar、Shear capacity、Shear crack

This research investigated the shear behavior of FRCC beams reinforced with AFRP bars. A four-point bending test was conducted. The test parameters were types of braided AFRP bars (plain and sand-coated) and PVA fiber diameters (27 μm and 100 μm). The fiber volume fraction of FRCC was set to 1%. The shear capacity of the FRCCs with a smaller fiber diameter showed a greater shear capacity for beams reinforced with both AFRP types. A conclusion could not be drawn for the effect of surface coating on the shear capacity at this stage, because the results vary across all cementitious materials.

Shear Behavior of FRCC Beams Reinforced with AFRP Bars

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1. INTRODUCTION

Fiber-reinforced cementitious composites (FRCC) members reinforced with fiber-reinforced polymer (FRP) bars combine high-strength, corrosion-resistant reinforcement and the post-cracking toughness, yielding greater load capacity, durability, and sustainability than conventional reinforced concrete. Ongoing research focuses on optimizing material properties, developing design guidelines, and exploring innovative applications to enhance the structural performance of these material combinations [1]. In this study, a four-point bending test was conducted to understand the shear behavior of a PVA-FRCC beam reinforced with aramid FRP (AFRP) bars.

2. EXPERIMENTAL PROGRAM

Rectangular beam specimens with a dimension of 160 × 230 × 1500 mm were prepared to study the shear behavior of PVA-FRCC beams reinforced with AFRP bars. The dimension, reinforcement detail, and sectional view of the specimens are shown in Fig. 1. The beams are reinforced with two AFRP bars with a diameter of 13.7 mm on the compression side and four on the tension side. Steel couplers filled with expansion agent are used as anchorage at both ends of the reinforcement bars. The test parameters are types of braided AFRP bars with different surface coatings (plain and sand coated) and PVA fiber dimensions (27 μm and 100 μm in diameter) for FRCC. The fiber volume fraction of FRCC was set to 1%. To investigate the effect of fibers in FRCC, the specimens without fibers were also tested. The specimen IDs are a combination of the main bar type, FRCC fiber type, fiber diameter, and fiber volume fraction. The specimen ID "MT" is given for the specimens without fiber.

Table 1 shows the mechanical properties of FRP bars. Fig. 2 shows the fibers for FRCC used in this study. The mechanical properties of PVA fibers, the mixture proportion, and compressive properties of FRCC, including specimen ID, are listed in Tables 2 and 3. ϕ100mm by 200mm cylindrical test pieces were used for the compression test of FRCCs.

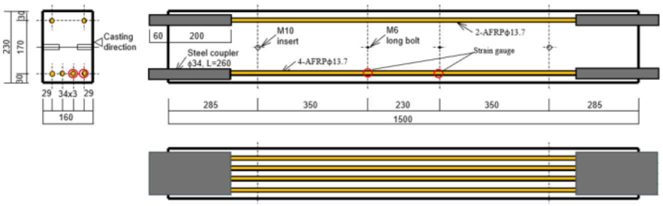

Fig. 1 Specimen dimension and reinforcement detailing

Table 1 Mechanical properties of FRP bars

Type	Surface type	Diameter (mm)	Tensile strength (MPa)	Elastic modulus (GPa)
AFRP	Braided AFRP (BA)	13.7	1170	68.6
	Sand-coated Braided AFRP (BAS)			

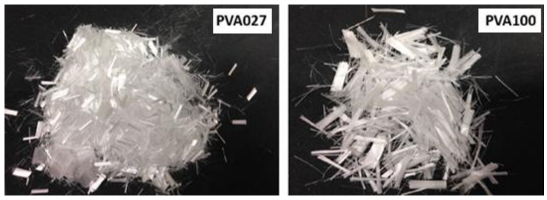

Fig. 2 PVA fibers

Table 2 Mechanical properties of PVA fibers

Fiber type	Diameter (μm)	Length (mm)	Tensile strength (MPa)	Elastic modulus (GPa)
PVA	27	6	1800	46
	100	12	1200	28

Table 3 Mixture proportion and compressive properties

Specimen ID	Unit weight (kg/m³)				σ_B (MPa)	E_c (GPa)
	W	C	FA	S		
BA/MT	380	678	291	484	45.3	16.4
BAS/MT					48.5	17.3
BA/PVA100-1					45.8	16.2
BAS/PVA100-1					46.7	16.8
BA/PVA027-1					48.0	15.5
BAS/PVA027-1					47.2	16.3

Cement: High early-strength Portland cement
Fly ash: Type II of Japanese Industrial Standard (JIS A 6201)
Sand: Size under 0.2 mm
Super plasticizer: Binder x 0.6%
Fiber volume fraction: 1%

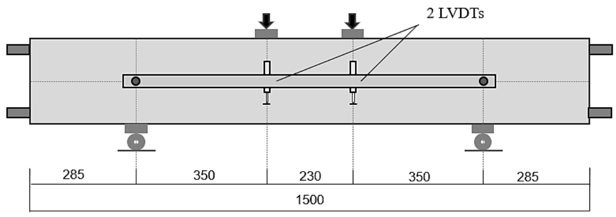

Fig. 3 Setup of loading and measurements

Keywords　FRCC, PVA fiber, AFRP bar, Shear capacity, Shear crack
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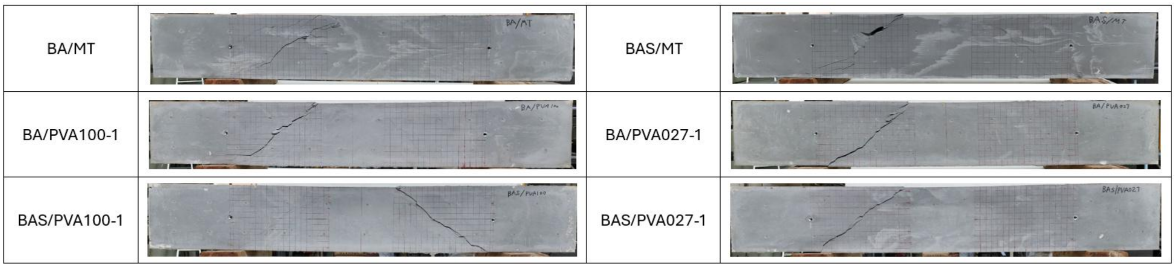

Fig. 4 Crack pattern at failure

A four-point bending test was performed using a 2000 kN compression testing machine with an assumption of a shear failure mode. The applied load, load point deflection using two linear variable displacement transducers (LVDTs), and strains at four points on the tension bars at the loading section were measured. Fig. 3 shows the loading and measurement setup.

3. EXPERIMENT RESULTS

In all specimens, shear cracks propagate, leading to a decrease in applied load. As shown in Fig. 4, all specimens showed shear cracks that propagate diagonally from the loading point to the supporting point. It is observed that for the same FRCC type, beams reinforced with sand-coated braided AFRP (BAS) exhibited a lower crack angle just after the maximum load compared to the beams reinforced with braided AFRP (BA), which reflects reduced interface slip.

The maximum shear force, deflection at the maximum load, and failure mode are listed in Table 4. The shear force-deflection relationship is shown in Fig. 5. The shear capacity of the FRCC for 27 μm and 100 μm, was 2.17 and 1.44 times greater than that of specimens without fibers for beams reinforced with braided AFRP (BA), whereas it was 2.50 and 2.11 times greater for beams reinforced with sand-coated braided AFRP (BAS) bars. The post-cracking stiffness of FRCC specimens was greater than that of the beams without fibers due to the bridging effect of the fibers.

It is known that the sand coating provides enhanced mechanical interlocking and friction with the FRCC, resulting in higher bond stiffness and improved stress-transfer efficiency. However, at this stage of the experiment, the effect of surface coating type on shear capacity is unclear because the results are inconsistent across all cementitious materials.

Table 4 Test result

Specimen ID	At maximum load		Failure mode
	Q_{max} (kN)	δ_{max} (mm)	
BA/MT	49.26	4.42	Shear
BAS/MT	36.32	3.84	Shear
BA/PVA100-1	70.72	4.56	Shear
BAS/PVA100-1	76.65	4.56	Shear
BA/PVA027-1	106.79	5.06	Shear
BAS/PVA027-1	90.92	4.17	Shear

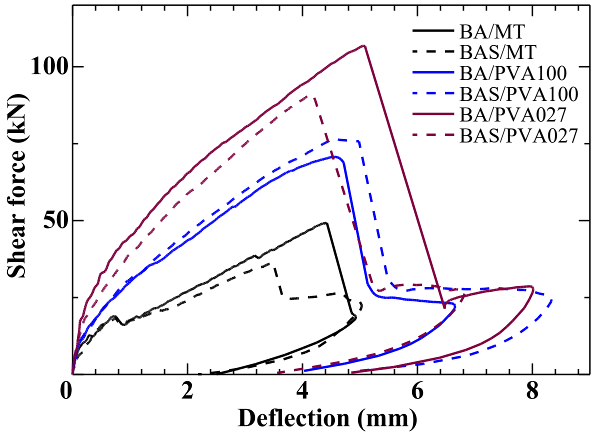

Fig. 5 Shear force-deflection relationship

4. CONCLUSION

1) The shear capacity of the FRCC for 27 μm and 100 μm PVA fiber was 2.17 and 1.44 times greater than that of specimens without fiber for beams reinforced with braided AFRP, whereas it was 2.50 and 2.11 times greater for beams reinforced with sand-coated braided AFRP.

2) At this stage of the experiment, the effect of surface coating type on shear capacity remains unclear because the results vary across all cementitious materials.

REFERENCE

[1] Shiferaw, H.; Kanakubo, T. Structural Performance of Fiber-Reinforced Cementitious Composite Members Reinforced with Fiber-Reinforced Polymer Bars: A Systematic Review. *Applied Science*, 2025, 15 (14), 7681.

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