日本建築学会大会学術講演梗概集
（関東） 2015 年 9 月

Bending Test of FRC Notched Beam with Various Polymer Fibers

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Bending Test Aramid Polyvinyl alcohol
Polypropylene Fracture energy CMOD

1. INTRODUCTION

With the development of polymer material, various synthetic fibers have become the best selection to improve concrete capacity and failure resistance without corrosion of fibers[1). However, more research is necessary to study the contribution of synthetic fibers to concrete matrix. The objective of this study is to make clear the influence of types of fibers to fracture properties of fiber-reinforced concrete (FRC) by the bending test of notched beams.

2. EXPERIMENTAL PROGRAM

2.1 Specimen

Aramid, polyvinyl alcohol (PVA) and polypropylene (PP) fibers (Fig. 1) were used with 1% volume fraction. The characteristics of the fibers are listed in Table 1. The mix proportion for base concrete is shown in Table 2. The water cement ratio was set to 0.50 and sand aggregate ratio was 0.60. The fresh and compressive properties are listed in Table3. The notched beam specimens with 100mm square section (Fig. 2) specified in JCI-S-001-2003 were used. The depth of the notch was set to 30mm. For each fiber, 6 specimens were tested to obtain the average data. Plain concrete without fiber (NF) was also tested.

2.2 Loading and measurement

As shown in Fig.2, three-point bending test was carried out. Two π gauges were set on the side of the specimen to obtain the crack mouth opening displacement (CMOD). For plain concrete, clip gauge was set on the mid-bottom of beam to measure CMOD directly. One LVDT was set on the back to measure the load point deflection (LPD).

3. TEST RESULTS AND DISCUSSIONS

3.1 Failure progress

Examples of the final failure patterns after loading are shown in Fig. 3. Except for Aramid-30 specimens, the load showed remarkable drop when the crack appeared from the notch. The maximum loads were observed as the matrix strength in these specimens. PP-30 and PVA-18 specimens showed the load increment after dropping with growing the crack. Aramid-30 specimens showed gradual failure through the loading.

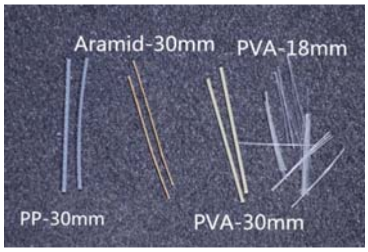

Fig. 1 Used fibers

Table 1 Characteristics of used fiber

ID	Density (g/cm³)	Length (mm)	Diameter (mm)	Tensile Strength (MPa)	Elastic Modulus (GPa)
Aramid-30	1.39	30	0.5	3432	73
PVA-30	1.30	30	0.66	900	23
PVA-18	1.30	18	0.2	975	27
PP-30	0.91	30	0.7	≧500	7-10.5

Table 2 Mix proportion of base concrete

Water cement ratio	s/a	Unit weight (kg/m³)			
		W	C	S	G
0.50	0.60	185	370	1006	676

Table 3 Fresh and compressive properties

ID	Aramid-30	PVA-30	PVA-18	PP-30	NF
Slump (cm)	14.5	15.5	6.5	23	23
Air (%)	5.7	3.9	1.3	6.5	7.1
Compressive Strength (MPa)	41.8	43.3	44.9	39.6	40.5
Elastic Modulus (GPa)	25.8	27.4	27.1	25.2	26.2

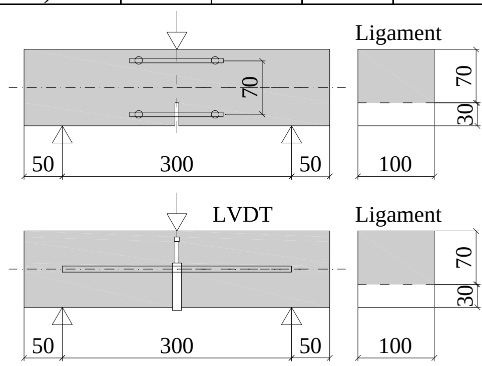

Fig. 2 Test specimen

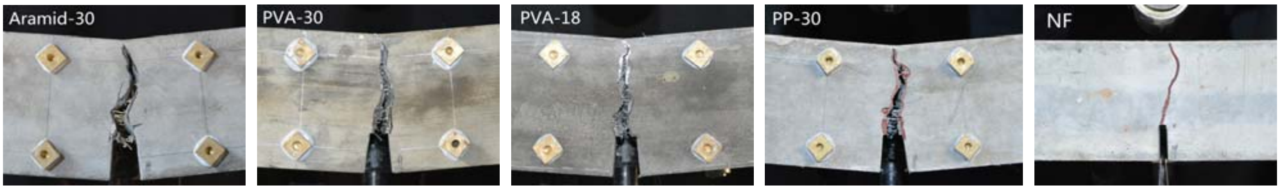

Fig. 3 Final failure patterns after loading

3.2 Load vs. CMOD relation

Examples of the load-CMOD curves are shown in Fig. 4. Comparing to the plain concrete, FRCs show a high ductility after cracking. The maximum load was observed after crack in Aramid-30 specimens. More than 50% of the maximum load can be remained until 8mm of CMOD. PP-30 specimen also showed high deformability that the second peak load was observed approximately 3mm of CMOD.

3.3 Fracture energy

The fracture energy until several CMODs is shown in Fig. 5. The error bars show the ranges of standard deviations by 6 specimens. PVA fibers show the lowest standard deviation. The fracture energy of Aramid-30 and PP-30 specimens increases gradually with the increase of CMOD while the fracture energy of PVA specimens barely changed.

3.4 Evaluation of fiber stress

The equivalent fiber stress, which is defined as Eq.(1) and (2), is newly introduced to evaluate the fiber effectiveness for crack bridging. Eq.(1) is derived in similar with the modulus of rupture for plain concrete. Stress distribution in the ligament section is assumed to be linear one. Fracture energy till 15mm CMOD is used for calculation. Fig. 6 shows the relationship between tensile strength of fiber and equivalent fiber stress. The straight line indicates the orientation factor 0.41 in case of the 3-D random distribution. It is considered that the fiber, which is plotted near the line, had more effectiveness for bridging in the capacity of its tensile strength.

$$\overline{f_b} = \frac{G_{F(CMOD)} \cdot A_{lig}}{0.75 \times 15} \cdot \frac{6}{4} \cdot \frac{S}{b \cdot h^2} \qquad (1)$$

$$\overline{\sigma_{f,b}} = \overline{f_b} \big/ V_f \qquad (2)$$

Where, $\overline{f_b}$: equivalent bending strength (N/mm^2), $G_{F(CMOD)}$: fracture energy (N/mm), A_{lig}: area of ligament (mm^2), S: span (mm), b: ligament width (mm), h: ligament height (mm), $\overline{\sigma_{f,b}}$: equivalent fiber stress (N/mm^2) , V_f: fiber volume fraction.

4. CONCLUSIONS

The maximum load was observed after cracking in aramid FRC specimen. PP FRC specimen showed high deformability that the second peak load was observed in several millimeters of CMOD. The equivalent fiber stress is newly introduced to evaluate the fiber effectiveness for crack bridging.

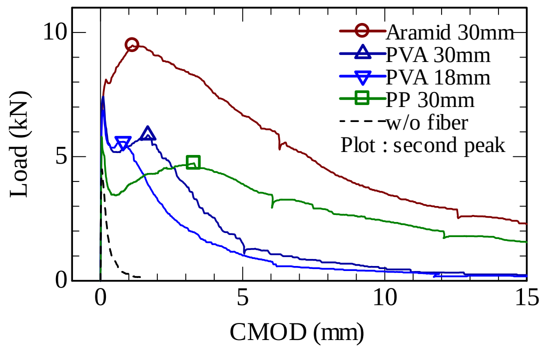

Fig. 4 Load-CMOD curve

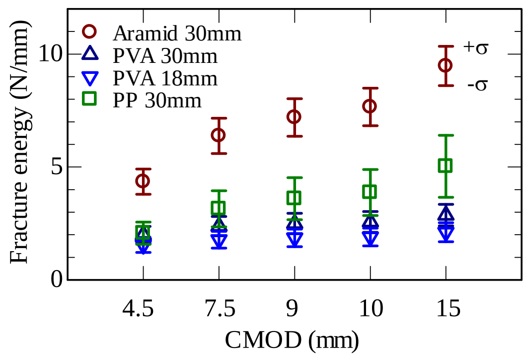

Fig. 5 Fracture energy

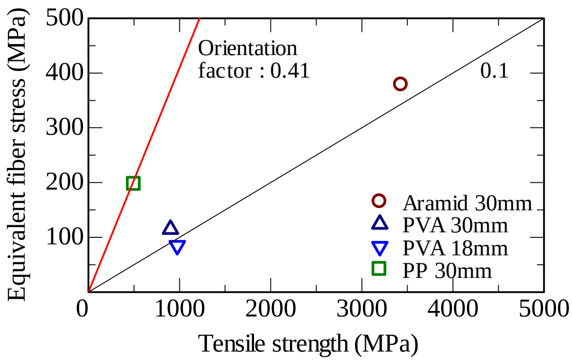

Fig. 6 Equivalent fiber stress

ACKNOWLEDGEMENT

This experiment was conducted under the committee activities for JIS development of polymer fibers for concrete organized by Japan Chemical Fibers Association.

REFERENCES

1) ACI Committee 544. 1R-96, State of the Art Report on Fiber Reinforced Concrete, pp. 39-57, 1996

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