POST CRACKING STRENGTH OF PVA FIBERS REINFORCED CONCRETE

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ABSTRAK

Rendahnya tegangan tarik dari material beton menyebabkan mudahnya timbul retakan pada sisi tertarik dari suatu elemen beton bertulang. Berbagai usaha telah dilakukan yang salah satunya adalah dengan menambahkan serta pendek pada adukan beton. Salah satu jenis serat yang dikembangkan adalah serat polyvinyl alcohol (PVA). Untuk keperluan sebagai bahan serat pendek material ini berdiameter antara 0.20 hingga 0.7 mm dengan panjang antara 12 mm hingga 30 mm. Material ini memiliki kekuatan lekatan yang tinggi terhadap bahan semen oleh karena sifat hydrophilicnya. Dengan kekuatan rekatan yang tinggi diharapkan bahan serat PVA dapat digunakan sebagai serat campuran pada bahan beton (FRC) untuk mengembangkan perilaku daktail pada beton setelah terjadinya keretakan. Salah satu parameter penting didalam perencanaan beton berserat atau Fiber Reinforced Concrete (FRC) adalah menetukan besarnya fraksi volume kritis yang diperluakan untuk memperoleh prilaku daktail yang diharapkan dimana tegangan setelah retakan pertama lebih besar.

Kata kunci *: PVA fibers, FRC, tegangan retak, beton.*

INTRODUCTION

One of the shortcomings of the concrete materials is the brittleness due to the low of tensile strength property of the concrete. This property causes the crack to propagate early at the low load. As well known that the ductility of brittle material will increase by introduce short fiber into concrete paste. The increasing of ductility of fibers reinforced concrete (FRC) is caused of the existing of bridging stress on crack section by short fiber. The PVA fiber has some advantages such as high bonding stress capacity to the cement matrix, uncorrosive materials, cheaper than steel fiber in the same volume, light in weight, etc. Figure-1 shows the PVA fibers manufactured for fiber

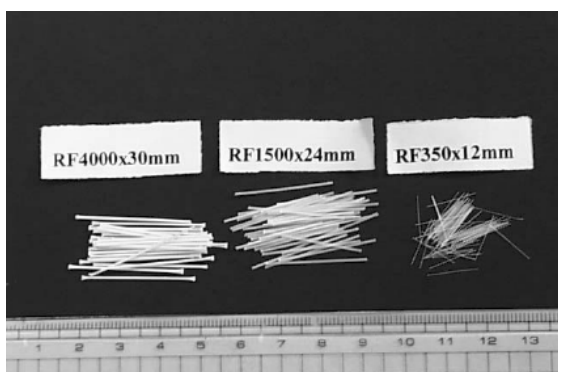

Figure-1 PVA Fibers manufactured for FRC

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reinforced concrete. As the main purposes of introducing short fibers into cementitious matrixes to increase of ductility of brittle matrix which is caused of the existing of bridging stress on crack section by short fiber. To achieve the purposes, the PVA fiber should have high bonding stress capacity with the cement matrix as well as has high tensile strength. PVA fibers are developed in various type and length. These fibers typically have a diameter of 0.20 to 0.70 mm. They are expected to show a strong bond with cementitious matrix due to their hydrophilic nature. In order to have effective bond to the cementitious matrix, PVA fibers have been developed in some different shape of the fiber cross section. The length of the fibers is varying from 12 mm to 30 mm. Comparing to the steel material, the density of the PVA fiber is much lower. The density of the PVA fiber is 1.3 gr/cm^3. The low light in weight implies to the prevention of the segregation of the fibers especially on the high slump concrete mortars.

FIRST CRACKING AND POST CRACKING STRESS

It is important to predict the first cracking strength of FRC due to applied load. The post cracking behavior of the FRC is greatly depending on the fiber volume fraction of the fibers. The strength at first cracking can be predicted by:

$$\sigma_{cc} = \sigma_{mu}(1 - V_f) + \alpha \tau V_f \frac{L}{d} \quad \text{................ (1)}$$

where :

V_f = Volume fraction of fibers.
L = Fiber length (mm)
d = Fiber diameters (mm)
L/d = Fiber aspect ratio
σ_{mu} = Tensile strength of the matrix (N/mm^2)
τ = Average bond strength at the fiber matrix interface (N/mm^2)
α = the reduction coefficient of fiber capacity before first cracking

Then, the maximum post cracking stress [1] can be predicted as:

$$\sigma_{pc} = \lambda \tau V_f \frac{L}{d} \quad \text{...................................... (2)}$$

where:

λ is reduction coefficient of fiber capacity after first cracking.

Table-1 Mixed proportion of fresh concrete per 1 m^3

W/C (%)	Cement C (kg)	Fine aggregate S (kg)	Coarse aggregate G (kg)	AE additive (cc)
55.0	342.5	815.0	961.3	1028

Table-2 Result of cylinder test.

Type	Compression strength f'c (Mpa)	Tensile strength Ft (Mpa)	Young Modulus E (Mpa)	Poisson ratio ν
I (Vf=1%)	38.8	3.11	2.97×10^4	0.207
II (Vf=2%)	37.4	3.06	3.26×10^4	0.222

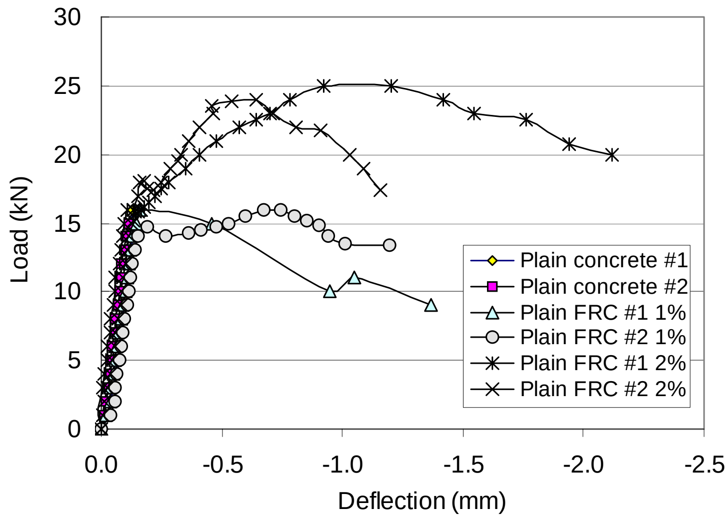

Figure-2 Load-Deflection Relationship of Beam Specimen

EXPERIMENTAL APPROACH

In order to clarify the value of α for PVA fibers, a bending test of PVA-fiber reinforced concrete beam was carried out. RF 4000 was used as the fibers in this study. The mixed proportion of beam specimen is shown in Table-1. Two types of FRC specimens were made that are V_f=1% as the Type I and V_f=2% as Type II, respectively. For comparison purposes, a plain beam specimen was also constructed as the control specimens. The plain beam is aimed to make comparison to the specimens with PVA fibers as well as to have the modulus of rupture (tensile strength) of the concrete matrix.

The beam specimen (400x100x100) was tested in four point bending test. The result of the cylinder test is shown in Table-2 while the result of bending test is shown in Figure-2. The load was applied gradually and it was measured by a load cell while measuring the deflection at span center. The first cracking on all specimens occurred when the applied load was approximately at 16 kN. After first cracking on the control specimen (specimen without PVA fibers), as it was predicted, the crack propagated fast caused final failure on the specimen. While, on the beam with 2% of PVA fibers, after first cracking, the beam did not lost its strength but the specimen was still going to bend. The maximum load was about 24 kN. On the specimens of type I with 1% of PVA fibers, after first cracking, the loading capacity was going down. However, due to the effect of the bridging of the PVA fibers on the cracking, the beams did not lost its strength suddenly as on the specimens without PVA fibers but it decreased slowly. The PVA fibers on the cracking section prevented the cracks to propagate fast. Based on the beam specimen results, it could be concluded that the strain hardening condition occur in type II for V_f=2% which is indicated by the increasing of loading capacity after firs cracking. The strain hardening occurs only if there are certain fiber volume fractions that can act as the bridge to prevent the propagation of cracks after first cracking. Figure-3 shows the split-failed specimen at the cracked section. It can be observed that most of PVA fibers on the cracked section were pulled out.

Figure-3 Split-failed specimen

POST CRACKING STRENGTH

Using of simple homogeneous beam under two loading points, the tensile strength of the matrix (tensile strength of the beam without PVA fibers) and the tensile strength of the PVA beam specimen are 4.65 N/mm^2 and 4.80 N/mm^2, respectively.

And then using Eq-1 by taking τ equal to = 5.5 N/mm^2, the value of α may be predicted to be 0.048.

The post-cracking strength of the FRC is influenced by the coefficient of $\lambda=\lambda_1\lambda_2\lambda_3$ which are represent the expected pull-out length ratio of fibers (λ_1), efficiency factor of orientation in the cracked state (λ_2) and the group orientation factor (λ_3), respectively. By taking the value of λ_1, λ_2 and λ_3 are equal to 1.0, 0.5, and 2.0, respectively, then, by Eq.2, the post cracking strength can be predicted to be 5.1 N/mm^2.

V. Conclusions

Based on this study, it can be concluded that :

(1) The beam specimen with 2% of PVA fibers, after first cracking, the beam did not lost its strength but the specimen was still going to bend. The maximum load was about 24 kN.

(2) The bridging effect of the PVA fibers on the cracking caused the beams did not lost its strength suddenly as on the specimens without PVA fibers but the it was going doing slowly.

(3) The strain hardening occurs only if there are certain fiber volume fractions that can act as the bridge to prevent the propagation of cracks after first cracking.

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