INFLUENCE OF STEEL FIBERS ON FLEXURAL BEHAVIOR OF PRESTRESSED CONCRETE BEAMS IN PRE-PEAK RANGE

Tokyo Institute of Technology	Student Member	○ WIN Myo Zarni
Tokyo Institute of Technology	Member	SIVALEEPUNTH Chunyakom
Tokyo Institute of Technology	Member	WATANABE Ken
Tokyo Institute of Technology	Fellow	NIWA Junichiro

1. Introduction

For the prestressed concrete (PC) structures, cracking is one of the serviceability requirements to be checked. By considering the growth of cracks after decompression, the resistance of steel fibers to crack propagation suggests that fibers could be utilized to improve the resistance of structural members to cracking at the service load. The main objective of this study is to investigate the effect of steel fibers and the prestressing force on the flexural behavior of PC beams in pre-peak range. Parameters considered in this experimental program were the magnitude of prestressing force and the volume of steel fibers in concrete.

2. Literature Review

The moment at ultimate stage, M_u was computed based on the equivalent stress block and the force equilibrium at the critical section. Shear carrying capacity of PC beams was calculated based on the following methods.

(1) Decompression moment method(M_0 method)

In this method, the effect of prestressing force in terms of β_n is used as the multiplier to the equation for concrete contribution, V_c (JSCE 2002). From many earlier investigations, the equation for contribution of concrete due to the diagonal tension failure, V_c, was proposed by Niwa (Niwa et al., 1986). The expression for shear carrying capacity of PC beams is $V_{M0}= \beta_n V_c$. The effect of steel fibers on the shear carrying capacity of PC beams was also taken into account by using the coefficient κ, (JSCE, 1999). Therefore, the expression for shear carrying capacity of PC beams including steel fiber is $V_u =(1+\kappa)\beta_n V_c$.

(2) Itoh's equation (M_{cr} method)

This method has been proposed by considering the summation of shear carrying capacity of concrete, V_c, and the resistance of flexural cracking, V_{cr} (Itoh et al., 1994). The expression for shear carrying capacity from M_{cr} method is $V_{Mcr} = V_c + M_{cr}/a$, where V_c is the shear carrying capacity from Niwa's equation (Niwa et al., 1986), M_{cr} is the moment corresponding to the first flexural crack and a is the shear span.

3. Experimental program

The experimental program consisted of four specimens and their reinforcement details are shown in **Fig. 1**. Yield strength and modulus of elasticity of PC bars used in the experiment were 1080 N/mm^2 and 200000 N/mm^2. The mix proportion in terms of water-to-cement ratio was 35% for all beams in order to obtain the compressive strength of concrete of 55 N/mm^2 at 14 days. Details of mix proportion are tabulated in **Table 1**. Steel fiber with crimped ends was used in this experiment, the length was 30 mm, the diameter was 0.6 mm and the tensile strength was 1000 N/mm^2. The name, the effective prestress introduced to the PC bars and the fiber volume content for each specimen is shown in **Table 2**.

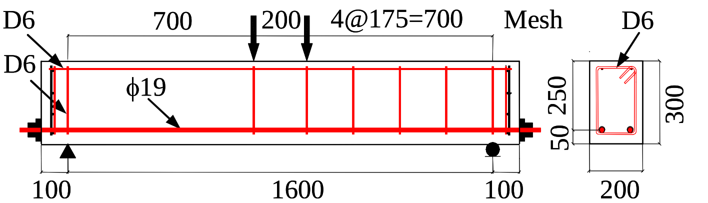

Fig. 1 Detail of beam reinforcement (unit: mm) Cross-section

Table 1 Mix proportion

W/C (%)	s/a (%)	W (kg/m^3)	C (kg/m^3)	S (kg/m^3)	G (kg/m^3)	SP (g/m^3)
35	53.1	165	471	914	790	3680

W = water, C = early strength cement, S = fine aggregate
G = coarse aggregate, SP = superplasticizer

Table 2 Test beam characteristics

Name	Effective prestress of PC bars (N/mm^2)	Fiber volume content (%)
P100F0.0	100	0.0
P100F1.0	100	1.0
P150F0.5	150	0.5
P200F0.5	200	0.5

Keywords: prestressed concrete, effective prestress, steel fiber, flexural crack, crack width, deflection
Contact address: 2-12-1 M1-17 O-okayama, Meguro-ku, Tokyo 152-8552, Japan Tel: 03-5734-2584, Fax: 03-5734-3577

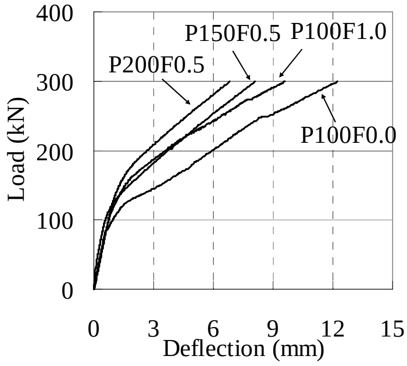

Fig. 2 Load-deflection curves

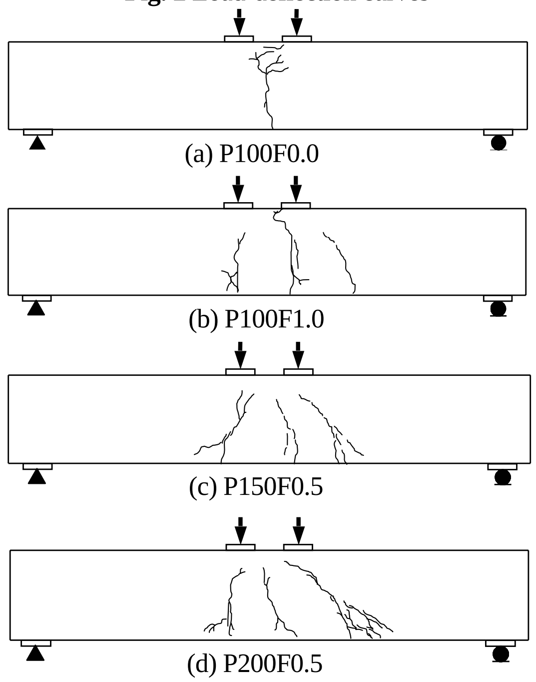

Fig. 3 Crack patterns of tested beams

Table 3 Comparison of measured values

Specimen	P_{crack} (kN)	Maximum crack width (mm)	Maximum deflection (mm)
P100F0.0	97	0.69	12.3
P100F1.0	98	0.36	9.6
P150F0.5	130	0.21	8.9
P200F0.5	171	0.08	6.8

4. Testing and analyzing

All the beams were simply supported and subjected to a four-point bending test.

(1) Load-deflection relationship

The responses of load versus deflection for all the beams from 0 kN to 300 kN are illustrated in **Fig. 2**. For beams P100F0.0 and P100F1.0, the deflections of P100F1.0 (fibers 1%) were smaller than that of P100F0.0 (fibers 0%). It shows that the addition of steel fibers can reduce the deflections of the PC beam under the same load level. On the other hand, the deflections of P200F0.5 (effective prestress: 200 N/mm^2) were also smaller than P150F0.5 (effective prestress: 150 N/mm^2). It is found that the deflection is smaller with the increase in effective prestress.

(2) Cracking behavior and crack width

Figure 3 shows the crack patterns for all beams at the same stage of loading at 300 kN. Applied load at first flexural crack, P_{crack}, maximum crack widths and deflections for all the beams at applied load 300 kN are also summarized in **Table 3**. Only one flexural crack was observed in P100F0.0 (fibers 0%), however, several cracks appeared in P100F1.0 (fibers 1%). The influence of steel fibers on the first crack load, P_{crack} was not observed. The number of cracks was greater and crack widths were smaller in P100F1.0, because the steel fibers across cracks helping the beam to hold together (bridging effect) until the maximum applied load. For P150F0.5 and P200F0.5, their crack patterns were similar, however, P_{crack} was higher and the crack widths were smaller in the case of larger effective prestress. It was found that the crack width was decreased with the increase in the effective prestress.

5. Conclusions

(1) The number of cracks increases and the maximum crack width is smaller in PC beams with steel fiber compared with the beam without steel fiber.

(2) The deflection at 300 kN is smaller when the steel fibers are added to the PC beams.

(3) Loading resistance at the first flexural crack, P_{crack} depends on the prestressing force, not on the amount of steel fibers.

References

1. Japan Society of Civil Engineers (JSCE) (2002): *Standard Specification for Concrete Structures [Structural performance Verification]*.
2. Japan Society of Civil Engineers (JSCE) (1999): Guidelines of Design for RSF Piers, Concrete Library. (in Japanese)
3. Niwa, J., Yamada, K., Yokozawa, K. and Okamura, H. (1986): "Revaluation of the Equation for Shear Strength of Reinforced Concrete Beams without Web", *Journal of Materials, Concrete Structures and Pavements, JSCE,* No.372/V-5, pp.167-176. (in Japanese)
4. Itoh, T., Yamaguchi, T. and Ikeda, S. (1994): "Flexural Shear Behavior of Precast Segmental PC Beam", *Proceedings of the Japan Concrete Institute*, Vol. 16, No.2, pp.967-972. (in Japanese)