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EFFECT OF CRACKING ON SERVICEABILITY OF FIBROUS CONCRETE

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ABSTRACT

In many types of concrete structure loss the serviceability due to wide cracking or large deflection, and it should be repair it as early as possible. As very important structures, such as the tunnel of super express railway, which has a drop of concrete fragment, was a lead to severe social accident. The fiber is expected to be useful in order to improve the serviceability and to prevent a drop of concrete fragment. The performance of concrete with fibers is judged by the flexural toughness obtained by load-deflection curves. The flexural toughness of concrete is different by the different types of fiber and it can express well the toughness of RC members at failure. Sometimes, it is difficult to use the flexural toughness in order to judge the behavior of concrete structures under service load. From the result of cracking on concrete beam cyclic applied load, the necessity of adequate method to judge the performance of concrete with different types of fiber is discussed.

KEYWORDS

Cracking, serviceability, flexural toughness, polypropylene fibers, steel fibers

INTRODUCTION

There are several types of fiber for concrete. They have their own characteristic, such as, steel fibers has high dynamical performance, but it is rust [1, 2]. On the other hand, polypropylene fibers is elastic and flexible, it does not pierce the hands or the feet of the workers under construction. But concrete with polypropylene fibers can not be expected as high toughness at failure as concrete with steel fibers [3]. Because the Young's modulus of polypropylene fibers is about one tenth that of steel fibers, almost it is the same as that of concrete. If the fibers is used in order to improve the toughness of concrete structures at failure, steel fibers may be the best and the flexural toughness obtained by load-deflection curves is good remarks to express the performance of concrete with fibers.

The purpose of the usage of fibers is diversified. Sometimes, it is used to restrict the cracking due to drying, or it is used to prevent the spalling of concrete fragment [4, 5]. Recently, the fibers are also used in order to improve the serviceability of concrete structures. In these cases, it may be inadequate to use the flexural toughness to decide the type of fiber to be used.

TABLE1
MIX PROPORTIONS OF CONCRETE

Max size (mm)	Air (%)	Slump (mm)	W/C (%)	s/a (%)	Weight per unit volume (kg/m^3)				
					W	C	S	G	SP
20	2.0	150	46.0	45.0	159	350	800	1,040	1.75

SP: Superplasticizer

The concrete structures are continually subjected to oscillatory loads. The stresses due to the oscillatory loads cause fatigue in such structures. The phenomenon of irreversible and progressive damage in a material subjected to cyclic stress is called fatigue. Generally, concrete structures are designed as the reinforced steel is yielded. The failure of concrete structures by fatigue is also strongly affected by the yield of steel. On the other hand, a crack of concrete can form and then grow by fatigue and concrete structure loses the serviceability before the failure of concrete structure occurred. The growth of fatigue cracking in concrete is attributed to the inherent weakness of concrete in tension. Potentially useful improvements in the mechanical behavior of concrete can be affected by the incorporation of fibers [6].

In this study, the effects of the type of fibers that influence the composite behavior of reinforced concrete have been investigated under cyclic loading conditions. The aim was to quantify the delay in the fatigue crack initiation and further propagation in the concrete matrix due to the addition of fibers. In this study, two types of fiber was used, either polypropylene or steel fibers which are different especially in Young's modulus. The method to judge the performance of concrete with different types of fiber under service load is investigated.

EXPERIMENTAL PROGRAM

The proportioning of the concrete mixtures for testing is summarized in Table 1. Superplasticizer admixture was used as 0.5 % of the total cement. All concrete mixtures were prepared with ordinary Portland cement with 3.15 g/cm^3 density. The fine aggregate used in concrete was natural river sand with 2.55 g/cm^3 density and 2.3 fineness modulus. The coarse aggregate was crushed sand stone with 20 mm maximum size and 2.73 g/cm^3 density. Two types of fiber, either polypropylene fibers or steel fibers have generally been used in RC structural members with either 0.5 % or 1.0 % by volume. The fibers were replaced with a part of aggregate. The diameter and length of each fibers are 0.6 mm and 30 mm, respectively. The densities of steel and polypropylene fibers are 7.65 g/cm^3 and 0.92 g/cm^3, respectively.

In the test for flexural static and cyclic loading, four points loading was applied to the specimen. Deflection measurements were obtained using a dial gage accurate to 0.01 mm. Measurements were recorded at mid-span. Cracks width was measured at the bottom of specimen using a microscope reading to 0.02 mm. The RC T-Beam tested in flexural cyclic loading is shown in Figure 1. The load fluctuated between 10 % and 60 % of the ultimate load obtained in static flexure test, that is, between 147 kN and 49 kN. The test loads were applied at 300 cycles per minute (5 Hz). The crack width was measured when each T-Beam was loaded up to the upper limit, 147 kN statically.

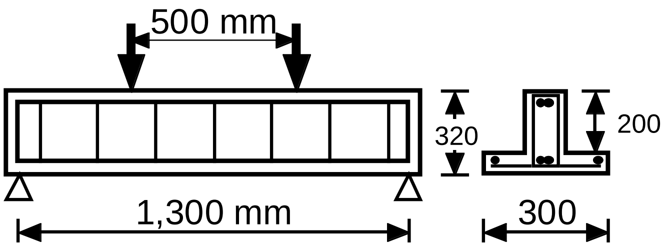

Figure 1: Set up of RC T-beam

EXPERIMENTAL RESULTS AND DISCUSSION

Figure 2 shows the load-deflection curves for concrete with different types of fibers. A significant difference in performance between steel and polypropylene fibers is found in the static flexural test. The flexural toughness is defined as the potential to absorb the energy with cracking. The area enclosed by load-deflection curve shows the flexural toughness. Japan Society of Civil Engineers recommends to use the flexural toughness factor σ_b obtained by Eqn. 1.

$$\sigma_b = \frac{T_b}{\delta_{tb}} \frac{l}{bh^2} \qquad (1)$$

where, δ_{tb}: 1/150 of span length, T_b: the area enclosed by load-deflection curves within the deflection equal to δ_{tb}, l: length of span, b: width of beam, h: height of beam.

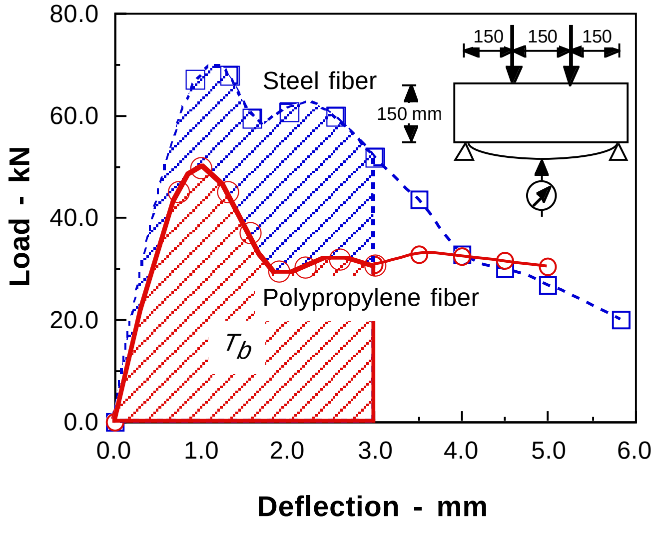

Figure 2: Load-Deflection curves for plain concrete reinforced with different type of fibers

The flexural toughness factors σ_b of concrete with polypropylene and steel fibers are 1.95 N/mm^2 and 4.36 N/mm^2, respectively. When the flexural toughness factor is used, the flexural toughness of concrete with polypropylene fiber is estimated as half as that with steel fiber. The load deflection curves of the two types of beam are shown in Figures 3 and 4. The results shown in Figure 3 and 4 were obtained from the beam with 2 stirrups and 4 stirrups, respectively. Irrespective of the number of stirrups, the largest increase in toughness was obtained when the concrete beams were reinforced with steel fibers followed by those reinforced with polypropylene fibers. It is clear that the flexural toughness factors σ_b can follow the toughness of concrete beams at failure.

Figures 5 and 6 show the number of cracks with load cycles. In Figure 5, the number of cracks of concrete with steel fibers is compared with that of control. It is noticed that, steel fibers have excellent performance in resisting crack initiation and propagation; thus; the ability of resistance to cyclic loading is increased greatly. In Figure 6, the number of cracks of concrete with polypropylene fibers is compared with that of control. The number of cracks of control specimen before the applying of cyclic load is more than that of specimen with fibers. The number of cracks of control specimen was increased rapidly after the applying of cyclic load and

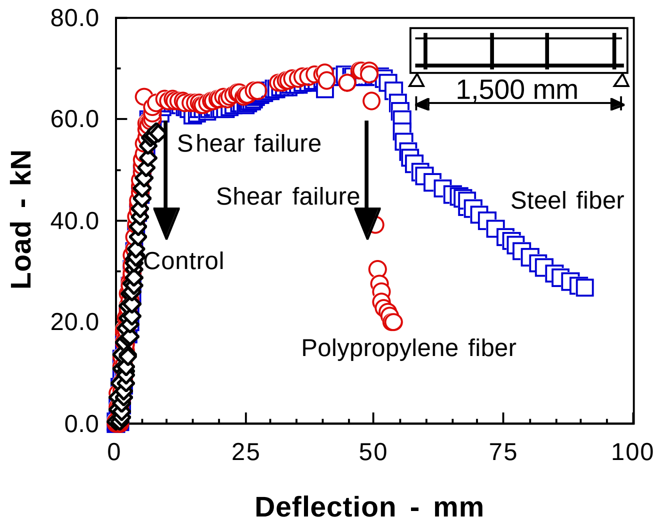

Figure 3: Load-Deflection curves for RC beam reinforced with different type of fibers

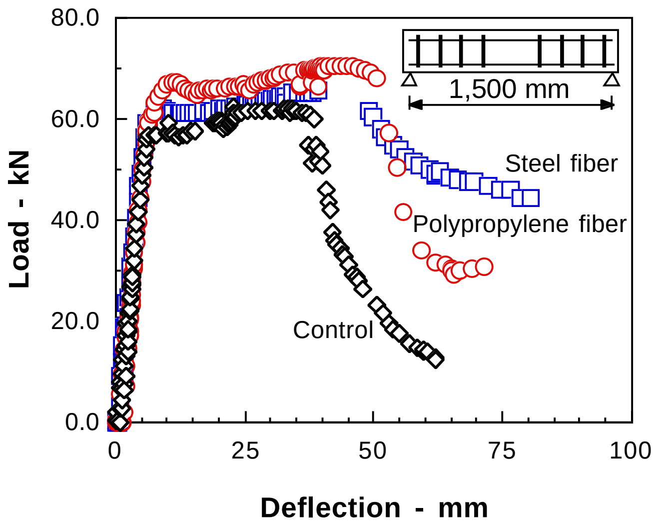

Figure 4: Load-Deflection curves for RC beam reinforced with different type of fibers

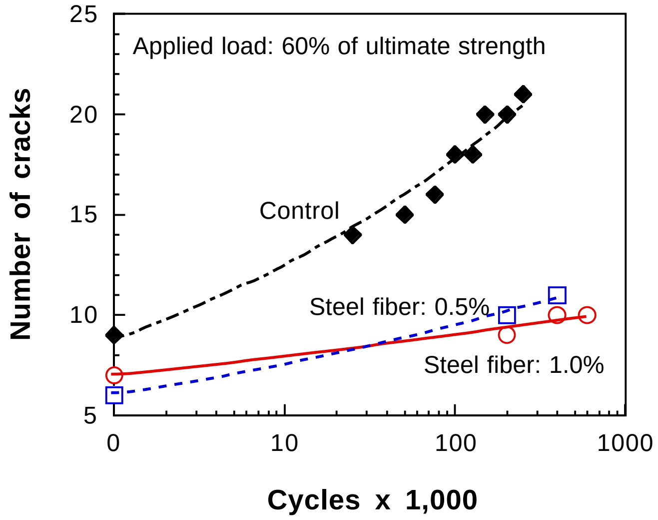

Figure 5: Effect of number of load cycles on number of cracks

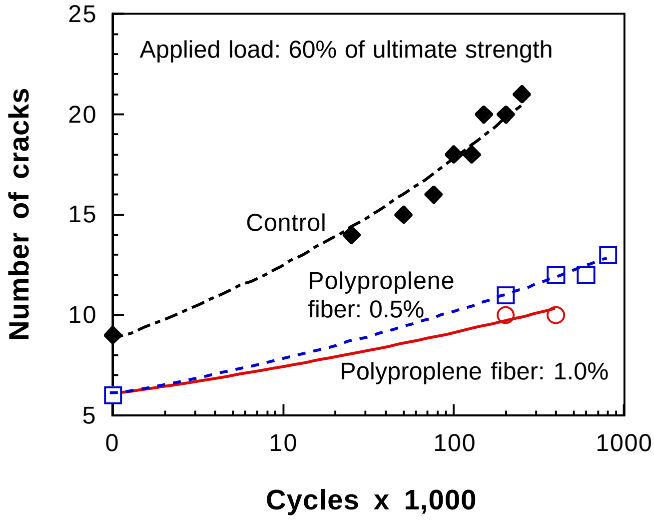

Figure 6: Effect of number of load cycles on number of cracks

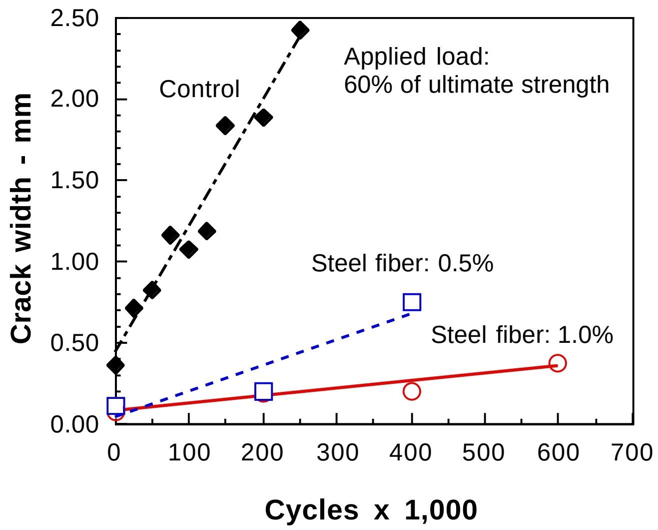

Figure 7: Effect of number of load cycles on crack width

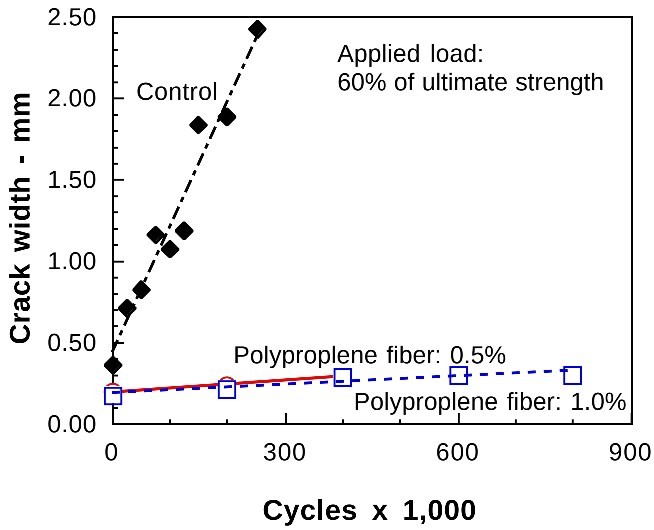

Figure 8: Effect of number of load cycles on crack width

broken at 250,000 cycles. On the other hand, the increase of the number of cracks of beams with fibers be less. The difference between concrete with polypropylene fibers and steel fibers in the number of crack is small.

Figures 7 and 8 show the crack width with the increase in number of load cycles. In Figure 7, the crack width of concrete with steel fibers is compared with that of control. In Figure 8, the crack width of concrete with polypropylene fibers is compared with that of control. Crack width which shown in these figures is average of the crack width for all cracks of each specimen. The development of crack width of control beam is quite different from that of beam with fibers. The crack width of control beam is over 5 times as wide as that of beam with fibers. The difference between concrete with polypropylene fibers and steel fibers in crack width is small, too.

Photos 1 and 2 show the control beam and polypropylene fibers beam just before failure. As clear from these photos, the decline of serviceability of control beam can be confirmed. The failure cycles of fiber's beams is between 500,000 and 800,000 cycles. It is not clear whether the fibers has played a role in prolonging fatigue life or increasing the capacity of fatigue load, because the fatigue is estimated by the order of cycles when concrete beam is broken not by the number of cycles itself. It is noticed that the number of cracks and crack

Photo 1: Mode of failure of control beam

Photo 2: Mode of failure of polypropylene fibers beam

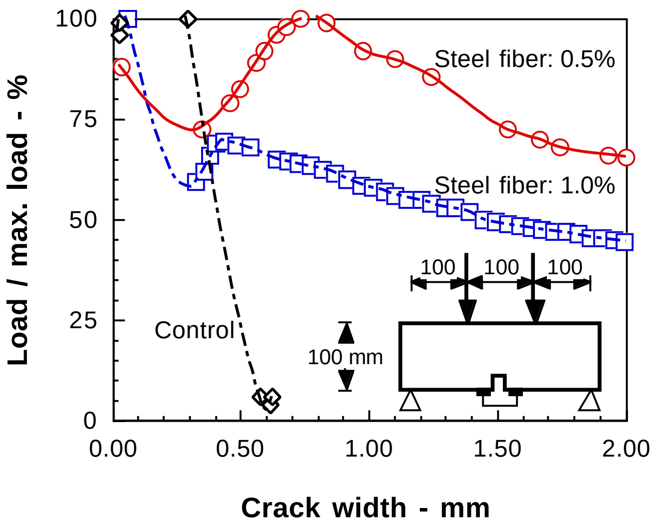

Figure 9: Effect of ratio of load / max. load on crack width

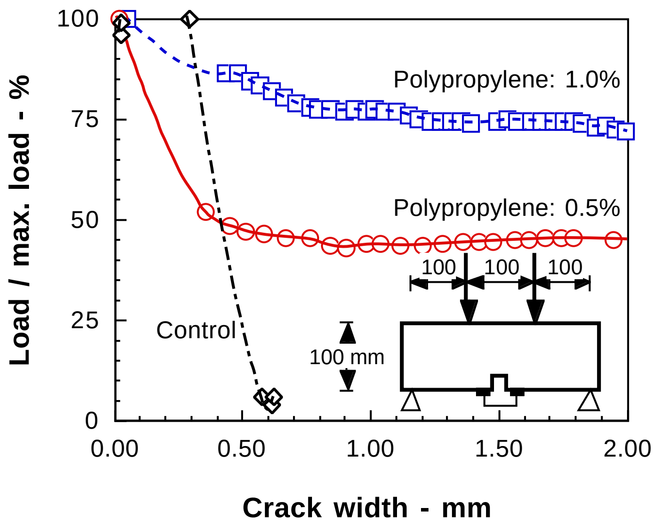

Figure 10: Effect of ratio of load / max. load on crack width

width is not increased so much when the fibers is used. The fibers can restrict the crack propagation under service load even if polypropylene fibers whose Young's modulus is about one tenth of steel fibers is used.

These results can not be explained the flexural toughness factor obtained by Eqn. 1. A number of previous experimental investigations have also established that cyclic loading not only affects the strength but also the serviceability, such as deflection and crack width, of reinforced concrete members [7].

Figures 9 and 10 show the relationship between crack width and load. The result shown in Figures 9 and 10 are obtained by using concrete with steel fibers and polypropylene fibers, respectively. The vertical line of these figures is the ratio between applied load and the maximum load. The crack width was measured at center of specimen. The specimen was made 5 mm raid to introduce the cracking. The control specimen was suddenly broken when the crack width reached at 0.5 mm. However, the concrete with fibers sustained the load of the half of maximum load at 2.0 mm crack width. The relationship between crack width and load of concrete with polypropylene fibers is almost same as that with steel fiber. The crack propagation under cycle service load may depend on the sustaining ability of load after cracking.

CONCLUSIONS

The load deflection curves indicated the advantage of fibrous concrete versus control concrete in obtaining higher toughness. Also, the development of crack width of specimen without fibers was quite different than those with steel fibers or polypropylene fibers.

By comparison between steel fibers and polypropylene fibers in performance of flexural toughness and crack propagation, it was found that, steel fibers have good performance in flexural toughness than that of polypropylene fibers, on the other hand, steel fibers and polypropylene fibers have the same performance in crack propagation.

In spite of the Young's modulus of polypropylene fibers is about one tenth of steel fibers, it was noticed that the number of cracks and crack width was not increased so much when even polypropylene fibers is used.

In spite of the flexural toughness can describe the toughness of concrete structural members with fibers at failure, it is not easy to use it in order to explain the propagation of cracking under service load.

It is necessary to express the sustaining ability of load after cracking by an adequate estimating method. In addition, the reliable and easy method to judge the performance of concrete with fibers is necessary that everybody can choose the adequate fibers in order to improve the serviceability of concrete structures.

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