Application of Unresin Continuous Carbon Fibers as Flexural Reinforcement in Concrete Structures

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1. INTRODUCTION

The financial expense associated with the repair of existing corrosion-damage steel reinforced concrete structure is high. The construction industry needs to seek alternatives to steel reinforcement. Recently, some uncorrosion materials such as carbon fibers have been emerged as a promising material for enhancing the corrosion resistance of reinforced concrete structures. In particular, carbon fibers offer some great potential for use in reinforced concrete structure under corrosive condition. The advantages of unresin carbon fibers (Fig.1) include higher tensile strength and stiffness to weight ratio than CFRP (Carbon Fiber Reinfroced Plastics), resistance to chemical attack, flexible, ease handling and easy carrying and cutting. This paper presents the flexural behavior of the concrete beam reinforced by uncorrosive unresin continuous carbon fibers as a substitute for steel reinforcement.

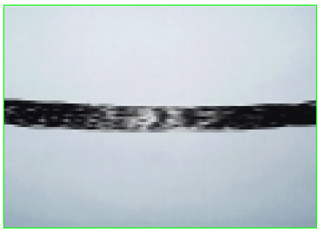

Fig.1 Unresin Carbon fiber

2. SPECIMENS

The tested concrete beams are divided into two series according the concrete strength. Series I and II have concrete strength of 35 Mpa and 60 MPa, respectively, and A, B and C have reinforcement ratio of 1.34%, 1.12% and 0.89%, respectively (Table 1). The simply supported beams have span length of 1400 mm and are subjected to two equal loads placed symmetrically at the center of the beams, as shown in Fig.2. Because of the surface of carbon fiber is smooth, carbon fiber that embedded in concrete develope bond by adhesion and by a small friction. Both of this will quickly lost when the reinforcement is loaded in tension. Based on this reason , the D10-steel bar is used as an end anchor in this study. The used carbon fiber has 24 sub strands per one strand, and 3000 micro fibers per sub strand and its properties are presented in Table 2.

Table 1 Test specimens

Series (MPa)	Specimen type	Number of strand*	Reinforcement ratio (%)
I (f'c=35)	I-A	12	1.34
	I-B	10	1.12
	I-C	8	0.89
II (f'c=60)	II-A	12	1.34
	II-B	10	1.12
	II-C	8	0.89

*) per group

3. TEST RESULTS AND DISCUSSION

The load-deflection relationship and the summary of experimental result are presented in Fig.3 and Table 3, respectively. Generally, flexural behavior of concrete beam reinforced with unresin continuous carbon fiber has the same behavior with concrete beam that reinforced with steel bar in which consists of linear part and nonlinear part. The linear part (stage 1) of carbon fiber reinforced concrete

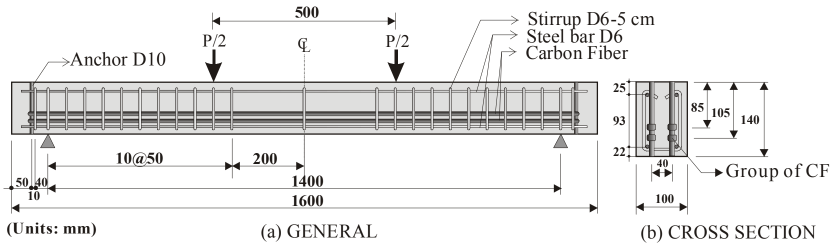

Fig. 2 Dimension of test specimen

Table 2 Properties of unresin continuous carbon fibers

Type of CF	E_{CF} (GPa)	f_t (GPa)	A (mm^2)	Density (g/cm^3)
24x3000	230	3.53	2.65	1.76

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is as same as the linear part of steel reinforced concrete beam. When the behavior enters in the nonlinear stage, the behavior is little different with the nonlinear behavior of the steel reinforced concrete beam. The nonlinear stage of carbon fiber reinforced concrete beam consists of three parts, that are ascending part (stage 2), descending part (stage 3) and a rather horizontal part (stage 4). Descending part of load-deflection relationship starts when concrete has crushed. Once the top of concrete beam has crushed, the load falls approximately 50%. And then, the horizontal part starts after descending part at load level approximately 50% of ultimate load. In this step, the deflection still propagates at almost same load level until the end of test, as can be observed through the load-deflection relationships (Fig.3). This last step is called as the second capacity of concrete beam reinforced by unresin continuous carbon fibers.

Table 3 shows the test results of the peak load and the second capacity load including the deflections where they occurred. As can be seen that as reinforcement ratio increases, the peak load also increases. This phenomenon also occurs when increasing of concrete strength from 35 MPa to 60 MPa. The effects of reinforcement ratio and concrete strength to the beam capacity are graphically presented in Fig.4 and Fig.5, respectively. Through the Fig.4, it can be observed that the peak load increases about 7.6% and 3.3% by increasing the reinforcement ratio form 0.89% to 1.12% and from 1.12% to 1.34%, respectively for Series I, and also increases about 12.7% and 8.7% by increasing the reinforcement ratio from 0.89% to 1.12% and from 1.12% to 1.34% for Series II, respectively.

And, through the Fig.5, by increasing the concrete strength from 35 MPa to 60 MPa, the results show that the peak load increases about 13.7%, 18.9%, and 25.2% for specimen with reinforcement ratio of 0.89%, 1.12% and 1.34%, respectively.

4. CONCLUSION

The unresin continuous carbon fibers with end anchors can be a good alternatives to steel reinforcement in the concrete beam. The concrete beam reinforced by unresin continuous carbon fibers has a typical flexural behavior, even after peak load. After peak load, the load-deflection curve falls about 50% and then the deflection still propagates at almost same load level till the end of test.

5. ANCKNOWLEDGEMENT

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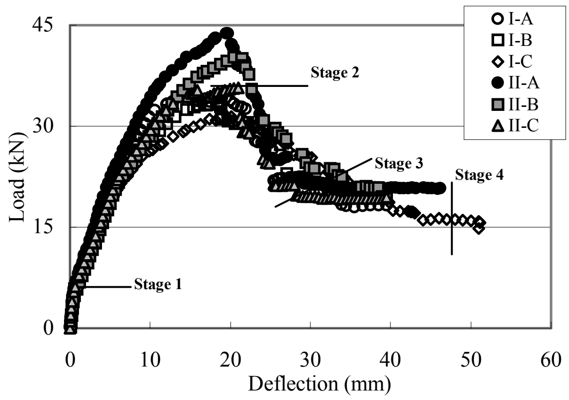

Fig. 3 Load-Deflection curves

Table 3 Summary of experimental result

Specimen type	f'c (MPa)	Peak load		Second capacity	
		Load (kN)	Defl. (mm)	Load (kN)	Defl. (mm)
I-A	37.2	34.9	14.8	22.3	26.5
I-B	37.2	33.8	18.3	21.7	27.6
I-C	37.2	31.4	20.1	17.5	40.3
II-A	58.8	43.8	19.6	21.5	30.2
II-B	51.1	40.2	21.0	21.2	25.7
II-C	56.8	35.7	17.0	22.1	29.1

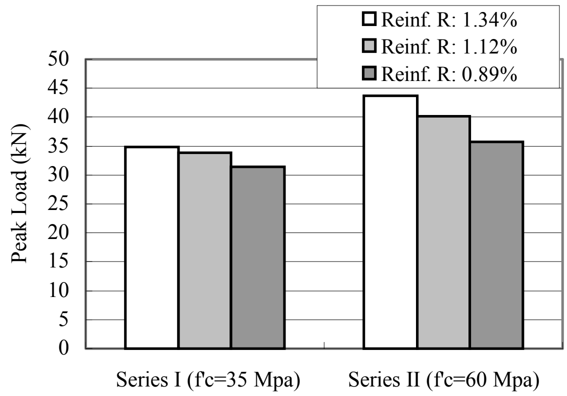

Fig. 4 Effect of Reinforcement ratio

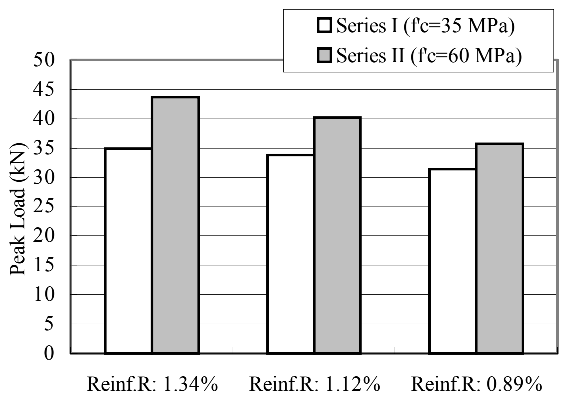

Fig. 5 Effect of Concrete strength