APPLICATION OF CFRP ROD WITH U-ANCHOR TO PRESTRESSED CONCRETE STRUCTURES

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1. INTRODUCTION

As a solution to the corrosion problem for rebars in concrete structures, fiber reinforced plastic (FRP) has been introduced to prestressing technology as a potential replacement for steel tendon. Among various types of FRP, carbon fiber reinforced plastic (CFRP) is the best alternative material due to its advantages such as high ratio of strength to mass density, excellent corrosion resistance, highest tensile modulus of elasticity, etc. [1]. However, the disadvantages of CFRP such as high cost, low modulus of elasticity (compare to steel reinforcement), anchoraging problem when CFRP is used in prestressed concrete structures, jointing method, etc., have limited the use of CFRP in wider application. In order to reduce the disadvantages of CFRP, an innovative CFRP has been introduced. The main characteristic of this CFRP, hereafter called Super CFRP, is the existing of U-anchor on both ends of the rod. The manufacturing process of CFRP has been reported by T.Ohta et al. [2,3].

2. ANCHORAGING CAPACITY OF U-ANCHOR

Continuously linked strands in forming of U-anchor during manufacturing process cause no joint between the rod and the U-anchor. This leads to the possibility of full transfer of the rod strength. U-anchor consists of two main parts, those are the circular loop and the straight-angled part. In order to clarify the anchoraging capacity of U-anchor, a tensile test and a pullout test were carried out. It should be noticed here that the Super CFRP made of 80 strands (CFRP-80S) was selected as a base material in this program. The mechanical properties of CFRP-80S is presented in Table 1. On the tensile test (6 specimens), U-anchor on both ends of rod (Figure 1) was directly loaded. While on the pullout test, the U-anchor was embedded into concrete under three types as shown in Figure 2 (3 specimens for each type). Those were totally embedded (type A), half embedded (type B) and un-embedded (type C), respectively.

The summary of tensile test and pullout test are presented in Table 2. Results indicated that, under direct loading, the U-anchor capacity was approximately 63% of the tensile capacity of rod. By embedding it into concrete, the U-anchor had capacity more than its rod capacity as indicated by the results of type A. While, the results of type B indicated that the maximum tensile capacity decreased to only approximately 30% of the rod capacity. This indicated that the circular loop of U-anchor influenced significantly the U-anchor tensile capacity. Furthermore, the results of type C indicated that bond capacity of the Super CFRP was 12.0 MPa in which approximately close to the bond capacity of the deformed steel bar.

Table 1 Properties of CFRP-80S

Tensile Strength	2300 MPa
Young's Modulus	147 GPa
Rod Diameter	8.85 mm
Tensile Capacity	140 kN

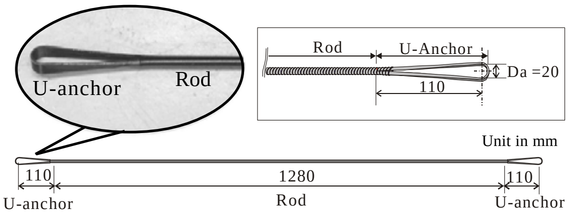
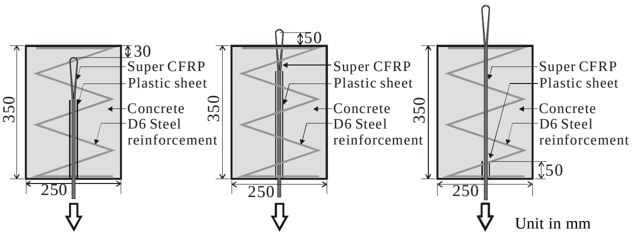


Figure 1 Super CFRP with U-anchor



(a) Type A (b) Type B (c) Type C

Figure 2 Specimen for Pullout Test

Table 2 Summary of Tensile Test and Pullout Test

	Tensile Test	Pullout Test		
		Type A	Type B	Type C
Pmax (kN)	88	152	49	100
Bond Stress (MPa)	-	-	-	12.0
Failure Mode	Rupture on U-anchor	Rupture on rod	Pulled out	Pulled out

3. PRESTRESSED CONCRETE BEAM

(a) Specimen

For simulation purposes, two specimens were prepared; one for PC beam and one for RC beam as a control specimen, respectively. The difference between them was only on the providing prestress force on PC beam specimen. The detail of specimen is shown in Figure 3. To prevent shear failure, the shear reinforcements made of steel bar 6 mm were provided. Two Super CFRPs were placed as prestressing tendons with

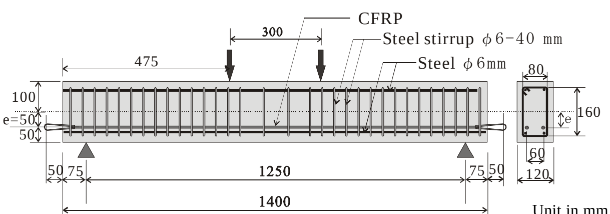


Figure 3 Specimen Detail

Keywords: CFRP, Prestressed, Anchorage, Concrete beam.
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eccentricity of 50 mm. For tensioning purposes, the U-anchor was connected using steel anchor to the tension device as shown in Figure 4.

(b) Stressing

Super CFRP-80S was stresses up to 70% of its U-anchor capacity (capacity under direct loading). This made the rod to be stressed up to 980 MPa (43% of the tensile strength of rod). The transferring of stress was done after 5 days when the concrete had compressive strength of 37 MPa with elastic modulus of 24.8 GPa. Due to the slip of the end-anchor, the strain loss near to the end-anchor was approximately 70%. However, the average strain loss of rod at inner part was 7%. This indicated that bond capacity of rod was sufficient to prevent the propagation of end-anchor slip. After transferring, the specimen was moved to the curing room under constant temperature. The concrete creep was measured for 9 days up to the testing day. Including the effect of concrete creep, the total loss prior to testing day was 13%.

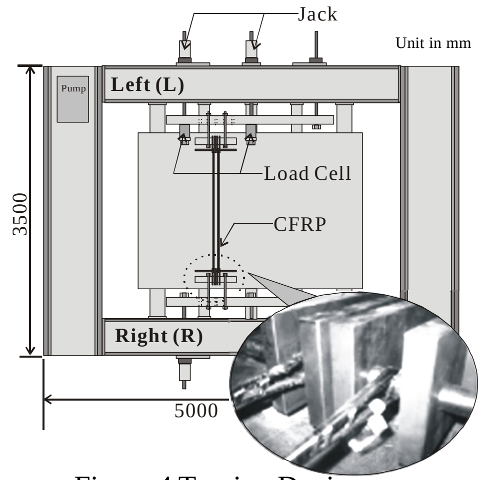

Figure 4 Tension Device

(c) Flexural Test

The static two loading points with distance of 300 mm were applied on the simply supported beams with span of 1250 mm. At testing, the concrete had compressive strength of 55 MPa with Young’s modulus of 31.8 GPa. The load-deflection relationship of both PC and RC beams are presented in Figure 5. Initially, both beams were un-cracking. The first cracking appeared on the RC beam when the load reached 17 kN, while the PC beams was still no crack. The first cracking on PC beam appeared when the applied load reached about 64 kN. With further loading, the beam stiffness decreased. On the RC beam, the maximum load was reached when concrete crushed at 112 kN of applied load, whereas, on the PC beam, the maximum load was reached when concrete crushed at 185 kN. Figure 6 shows the relationship between applied load and strain of CFRP. Including the prestressing effect, the maximum strain of CFRP in PC beam was approximately 14200 μ or 2090 MPa of stress. The photograph of crack patterns of both beams are presented in Figure 7. Result indicated that the cracks were distributed on both PC and RC beams.

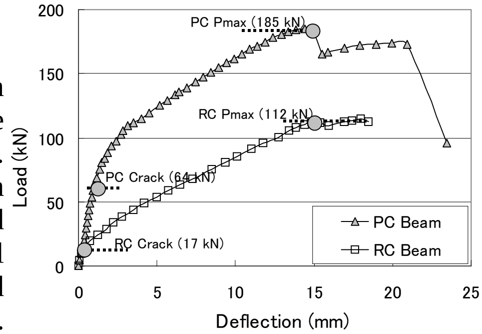

Figure 5 Load-Deflection Relationship

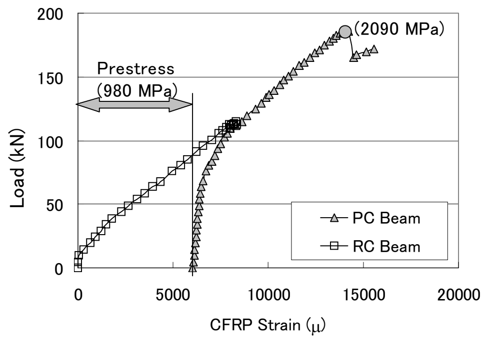

Figure 6 Load-CFRP Strain Relationship

The results indicated that the Super CFRP could be a potential solution for limitation of the application of CFRP caused by its disadvantages, especially about the anchoraging problem. Using U-anchor, a totally non-metallic concrete structures could be created with no more nightmare about corrosion.

4. CONCLUSIONS

From this study, the following conclusions were made:

(1) Tensile capacity of U-anchor under direct loading was about 63% of the rod tensile capacity. However, by embedding it into concrete, the U-anchor had tensile capacity more than the rod tensile capacity.
(2) Bond strength of Super CFRP to concrete was 12.0 MPa.
(3) The initial stress of 980 MPa had been transferred successfully into concrete with a total loss of 13%.
(4) Super CFRP with U-anchor could be a potential alternative for prestressing tendon.


(a) PC Beam


(b) RC Beam

Figure 7 Crack Pattern

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