PRESTRESSING AND FLEXURAL BEHAVIOUR OF PC BEAM REINFORCED BY CFRP ROD WITH U-ANCHOR

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1.Introduction

Due to the corrosion problem and the necessity for materials to have a long-term durability, there is an increasing need to introduce new materials that could be also used for repair some of the damaged reinforced concrete structures and to construct new structures that are able to resist corrosion. Because of that in the recent years Carbon Fiber Reinforced Plastics (CFRP) has been introduced. Lightweight, high strength, ease to be applied compared to traditional methods, and good durability were the main reasons for using CFRP to repair some bridges in several cities in the USA. However, CFRP has also some disadvantages such as high cost, low modulus of elasticity and anchoraging problems. A research program called Uni-Directional Carbon-Fibers Assembly System (UCAS) has been started in Kyushu University since 1999 to improve the properties of conventional CFRPs and to reduce its disadvantages. The CFRP manufactured by UCAS program that is called super CFRP is to be used in prestressed and non-prestressed concrete beams instead of tensile steel reinforcement [1].

2. Specimens

Two prestressed concrete beams and a non-prestressed beam reinforced by super CFRP with U-anchor have been made. The details of specimens are shown in Figure 1. The rod of CFRP U-anchor is shown in Figure 2. The super CFRP was made from 80 strands of UCCF T700S-12K; the properties are shown in Table 1. The shear reinforcements were made of 6mm steel bar. Two super CFRP rods were installed as prestressing tendons with eccentricity (e) of 50mm.

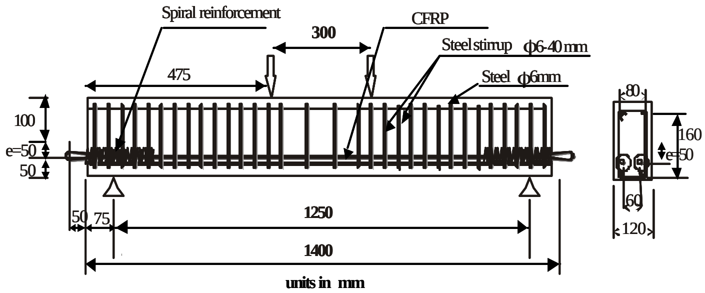

Figure 1. Specimen details

3.Prestressing

The CFRP rods were tensioned up to 62.5kN. This made the rod to be stressed to 1016 MPa (44% of the tensile strength of CFRP). The releasing was done after 5days, when the compressive strength of concrete reached 35.6 Mpa with Young's Modulus of 33.2 Gpa.

In the prestressed beams (pre-tension system), after releasing the tension forces, some of these forces will be transfer to the concrete as a compressive stress and some will be loss. Some of the losses occur during transferring. These losses are called immediate losses. Other losses occur progressively with time, as the tendon and concrete age and undergo inelastic deformations; the loss of prestress is 7%-15% of the initial tension force [2]. The computation of the losses of prestress is due to the slip of tendon bar, elastic deformation of concrete, the creep of concrete and the shrinkage of concrete. The graphs of strain distribution along the rods after transferring are shown in Figure 3. The loss of strain near to the ends of anchors due to the slip of the tendons was 75% of the initial value before releasing.

That means the strain, which transferred to concrete around the end of U-anchor, was approximately 25% and the effective development length was about 275mm.

The U-anchor reduces the effective development length and the loss of strain due to tendon slip. However, if there wasn't a U-anchor, the development length will be more than 275mm as approximately 30 times of CFRP rod diameter.

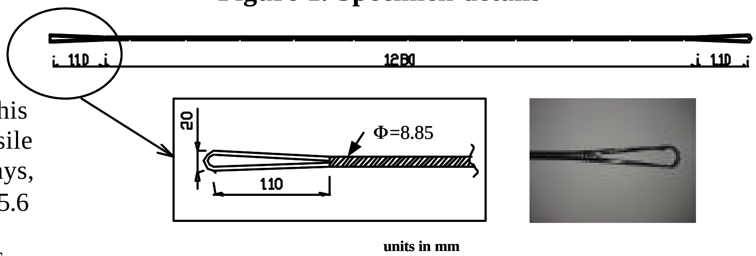

Figure 2. CFRP rod with U-anchor

Table 1. Properties of super CFRP-80S

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

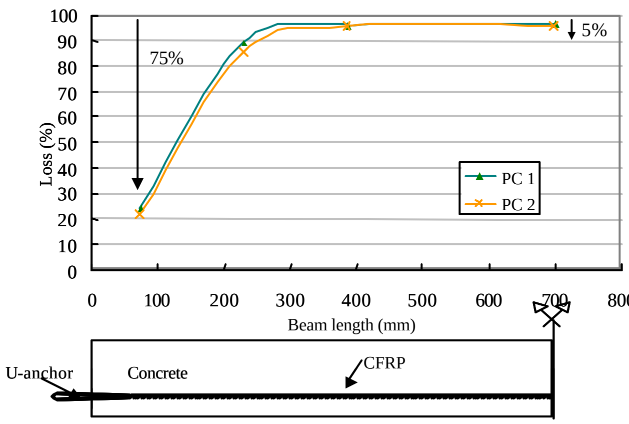

Figure 3. The strain distribution along the rods after transferring

At inner part of tendon, due to elastic deformation, the loss of strain was 5% of the initial value before releasing, which means approximately 95% of the initial value of stress before releasing was transferred to the concrete beam. After transferring, the beams were moved to curing room under constant temperature until bending test. While waiting for the testing, the concrete creep was also measured for 16 days simultaneously. The loss due to creep during these days was 2.5%. The total losses of strain up testing day were 7.5%. It should be noticed here that the creep of concrete continue with time 18-35% occurred in the first two weeks of loading 40-70% within 3 months and 60-83% within 1 year [2]. The graphs of strain distribution of span center cross section of concrete after transferring are shown in Figure 4. Results indicated that the concrete was stressed as be predicted by calculation.

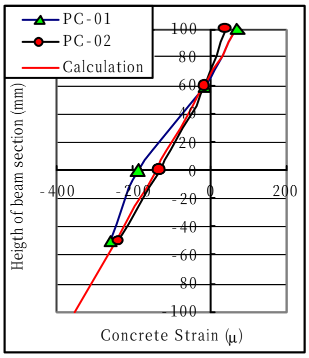

Figure 4. Concrete strain distribution due to prestressing

4.Bending test

The static two loading points with distance of 300mm were applied on the simple supported beams with span of 1250 mm. At testing, the concrete had compressive strength about 49 MPa with Young's Modulus about 35 GPa. The load-deflection relationship of all specimens is shown in Figure 5. Initially, the beams were un-cracking. The first cracking appeared on RC beam when the load reached about 15kN, while the PC beams were still no crack. The first cracking on PC beam appeared when the applied load reached about 62kN. With further loading, the beam stiffness decreased. On the RC beam, the maximum load was reached when concrete crushed at 117kN of applied load, whereas, on the PC beams, the maximum load was reached when concrete crushed about 135kN. Predicted cracking, ultimate load on PC and RC showed a good agreement. This indicated that the ordinary PC and RC design theory could be adopted in design of PC and RC reinforced by super CFRP with U-anchor.

The relationship between applied load and strain of CFRP including the prestressing effect is shown in Figure 6.the maximum strain of CFRP in PC beams was approximately 10000 μ. The photograph of crack patterns of beams are presented in Figure 7. The cracks were distributed on PC and RC beams.

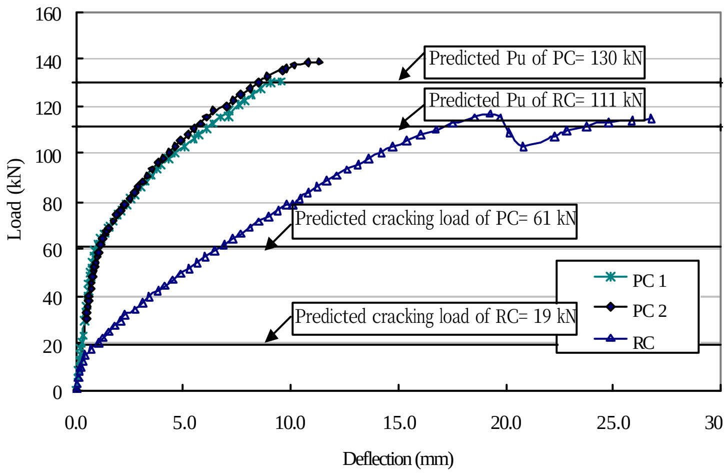

Figure 5. Load-Deflection Relationship

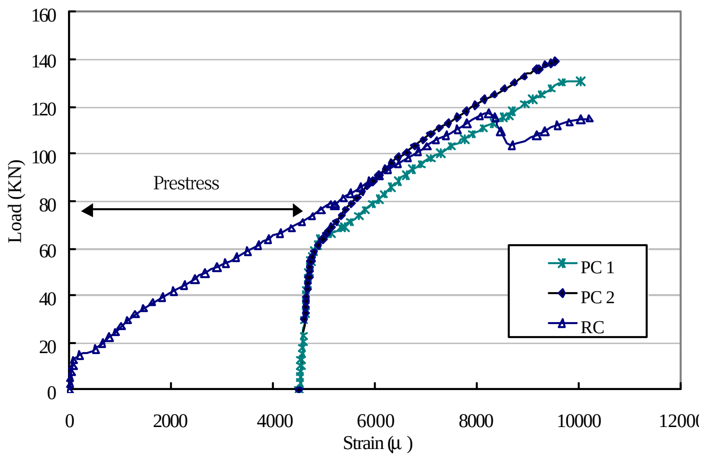

Figure 6. Load-CFRP Strain Relationship

5.Conclusion

(1) The loss of strain during transferring near the U-anchor was 75% from the initial value. However, the loss at inner part of tendon was only 5% from the initial value.
(2) The initial strain could be transferred to the concrete with total loss of 7.5% within 16 days.
(3) The crack load in PC beams is 3 times bigger than crack load in RC.
(4) Ordinary design theory of PC and RC could be adopted in design of PC and RC reinforced by the proposed CFRP with U-anchor.

(a) PC 1

(b) RC

Figure 7. Crack Pattern

References:

[1] R. Djamaluddin, S. Hino and K. Yamaguchi, "Innovative approach in manufacturing and application of CFRP rods with U-anchor for concrete structures" 4th International Conference in Advanced Composite Materials in Bridges and Structures, Canada, July 2004 pp.1-9.
[2] Prestressed Concrete (Transportation Dept. Damascus University) M. Fariz ABDIN