Static loading test of the flexural reinforced PC beams with pre-tensioned AFRP sheet

Hazama corporation Member ○ S. Sawada
Muroran Inst. of Tech. Fellow N. Kishi
Muroran Inst. of Tech. Member ○ AbdelAziz M. Aly
Muroran Inst. of Tech. Member Y. Kurihashi
Sumitomo-Mitsui Const. Fellow H. Mikami

1. Introduction

In order to establish a reinforcing method using pre-tensioned AFRP sheet for PC beams, four-point loading test of the beams was conducted varying dimensions of the beams and introduced pre-tensioned stress ratio of the sheet.

2. Overview of experiment

The specimens used in this experiment are listed in Table 1. In the table, these specimens are designated using dimensions of cross-section (A and B) and introduced pre-tensioned stress ratio *n* % of the AFRP sheet as Beam A/B-T*n* and reference specimens are named as Beam A/B-N which are not reinforced with AFRP sheet. Introduced pre-tensioned stress ratio was defined referring to nominal load-carrying capacity 1,176 kN/m. The beams have rectangular cross-section of 300 x 200 mm for A-type and 160 x 160 mm for B-type. Three PC tendons of ϕ12.7 and two PC tendons of ϕ9.3 mm for A and B type beams were casted in the lower fiber and the pre-stress was introduced using pre-tensioning method. Dimensions of the PC beams and arrangement of rebar, PC tendons, and AFRP sheet are shown in Fig. 1. Clear span of these beams is 2.8 m.

In this experiment, introduced effective pre-tensioned stress ratios of the PC tendons for Beams A and B were taken to be 35 and 55 % of tensile strength of tendons for Beams A and B, respectively. Bonding procedure of pre-tensioned AFRP sheet is as follows:

(1) Grit-blasting the bonding surface of PC beams to improve the bonding capacity and coating the surface with primer to smoothen the rough concrete surface; (2) bonding cross-directional AFRP sheet (unit mass of 435 g/m^2) in the region of 50 through 500 mm from the both supporting points to disperse widely the concentrated bonding stress; (3) making the warped surface in the upward direction smooth by filling epoxy-resin type putty which is due to pre-stress introduced in the beams; (4) pre-casting AFRP sheet due to impregnating epoxy-resin and curing it; (5) applying normal epoxy-resin on the bonding surface of PC beams and applying the special epoxy-resin for relaxing strain in the region of 200 mm from the ends of sheet instead of normal one; (6) introducing the prescribed tension force into the sheet, after that, bonding the sheet to the surface surcharging some pressure, and (7) after curing, releasing the tension force surcharged at the ends of sheet, and introducing the force in the sheet.

Table 1 List of specimens

Specimen	Section type	Designed pre-tensioned stress ratio* (%)	Actural pre-tensioned stress ratio* (%)	Introduced initial tensile strain (μ)
A-N	A	Non-strengthening		-
A-T0		-	-	-
A-T20		20 (70.6)	20.9 (73.6)	3,553
A-T40		40 (141)	41.3 (146)	7,021
B-N	B	Non-strengthening		-
B-T0		-	-	-
B-T20		20 (37.6)	22.0 (41.3)	3,740
B-T40		40 (75.3)	39.6 (74.5)	6,732

* ( ): Pretensioned force (kN)

3. Experimental Results

3.1 Load-Displacement Relation

The comparisons of load-displacement relationship between experimental and numerical analysis results are shown

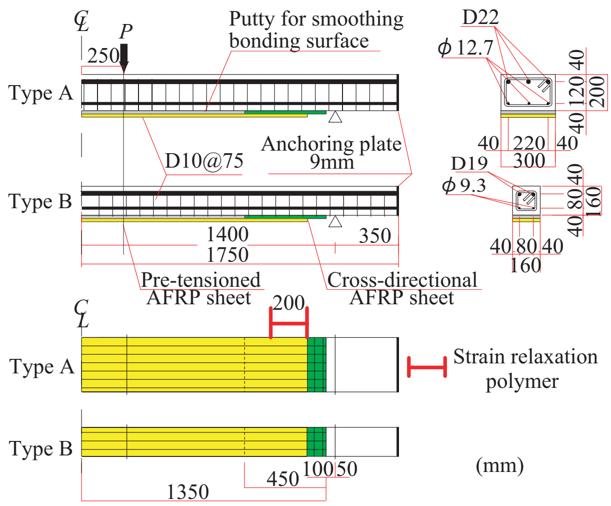
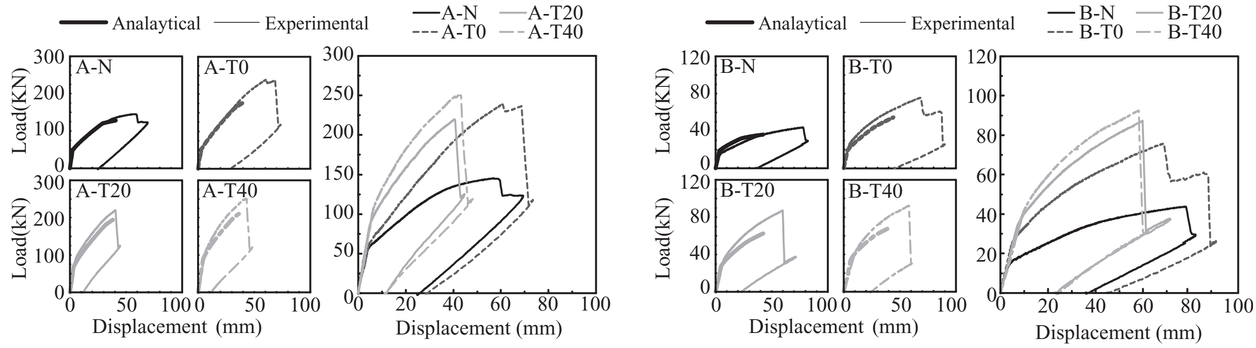


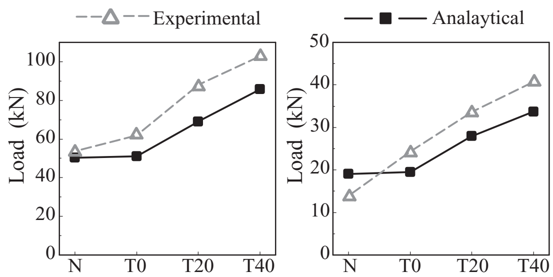
Fig. 1 Layout of reinforcement and AFRP sheet

Key words: PC beams, AFRP sheet, Flexural strengthening, Pre-tensioned bonding
Address: 〒 050-8585 Muroran Institute of Technology TEL 0143-46-5230 FAX 0143-46-5227



(a) Type A　　(b) Type B

Fig. 2 Comparison of load-displacement relations between experimental and analytical results



(a) Type A　　(b) Type B

Fig. 3 Flexural cracking load

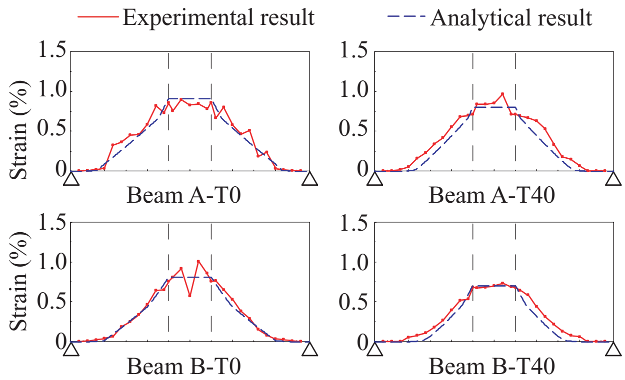


Fig. 4 Comparison of strain distributions for AFRP sheet

in Fig. 2, in which numerical analysis results were evaluated by means of multi-section method without the stiffness of putty following JSCE concrete standards. From the results, it can be observed that numerical analysis results give a good agreement with the experimental ones, and load-carrying capacities of the beams obtained from the experiments are greater than those from numerical analysis. This implies that the flexural load-carrying capacity of the reinforced PC beams with pre-tensioned AFRP sheet can be evaluated in the safety side by means of the multi-section method. From the experimental results, it can be observed that after crack occurring, flexural stiffness evaluated from the experimental results tends to be greater than that from numerical analysis. This may be due to the effects of warping the beams in the upward direction and the stiffness of putty.

3.2 Loading level at flexural cracks occurring

The comparisons of surcharged load at flexural crack occurring between experimental and numerical analysis results are shown in Fig. 3. From these figures, it can be seen that the load at crack occurring is increased due to reinforcing PC beams with pre-tensioned AFRP sheet. The loads for Beams A and B are upgraded with the rate of 40 and 63 %, respectively, refering to that in case reinforcing with non pre-tensioned AFRP sheet.

3.3 Strain distribution

Axial strain distributions of the FRP sheet at the ultimate state evaluated by numerical analysis are compared with the experimental results as shown in Fig. 4. From the figures, it can be observed that the numerical analysis results are good agreement with the experimental ones for all PC beams considered here. Then, it can be confirmed that bonding capacity between pre-tensioned AFRP sheet and concrete surface was kept enough up to the analytical ultimate state of the beams.

4. Conclusions

1) Bonding AFRP sheet with introduced pre-tensioned stress ratio of 20 % and 40 % on the tension side surface of PC beams, loading level at crack occurring can be upgraded up to the rate of 40 % and 63 % referring to that in case reinforcing PC beams with non pre-tensioned AFRP sheet;
2) Flexural loads-carrying capacity of the reinforced PC beams with pre-tensioned AFRP sheet can be evaluated by using the multi-section method in the safety side; and
3) Bonding capacity between pre-tensioned AFRP sheet and concrete surface is kept enough up to analytical ultimate state of the PC beams.