Effect of pre-tension force of AFRP sheet on load-carrying behavior of reinforced RC beams

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1. Introduction

In order to investigate the effect of pre-tension force introduced to AFRP sheet on load-carrying behavior of flexural reinforced RC beams, four-point loading test was conducted by varying pre-tension force introduced to AFRP sheets.

2. Overview of experiment

The specimens used in this experiment are listed in Table 1. These specimens are designated adding introduced pre-tensioned stress ratio *n* % referring to the nominal tensile strength of AFRP sheet after letter of "T" such as Beam T*n*. The control specimen is named as Beam N, which is not reinforced with AFRP sheet. The sheet used here is of 830 g/m^2 unit mass, 300 mm width and 1,176 kN/m nominal tensile capacity. The beams have a square cross-section of 220 mm width and depth. The clear span is 2,800 mm. The layout of the reinforcement and AFRP sheets are shown in Fig. 1.

3. Experimental Results

3.1 Load-Displacement Relation

The comparisons of load-displacement relationship between experimental and numerical analysis results are shown in Fig. 2. Here, numerical results were evaluated by means of multi-section method following the specifications of JSCE concrete standards. From this figure, it is observed that the flexural stiffness and loading level in the region from cracking level to ultimate state are increased according to an increment in the pre-tension stress ratio but the deflection at ultimate state is decreased. The comparisons of load-displacement relationships between Beams T*n* and Beam N obtained from the experimental results and the failure modes of Beams T*n* are shown in Fig. 3. From this figure, it is observed that: 1) the greater the pre-tension stress ratio is, the greater the flexural stiffness after cracking is and the bigger the load at main rebar yielding is; and 2) the failure mode of the beams tends to be sheet debonding after reaching the compressive failure of concrete corresponding to increasing of pre-tension stress ratio. The ratio of analytical moment at main rebar yielding M_y to analytical ultimate moment capacity M_u, failure mode obtained from experiments and predicted failure mode are listed in Table 2, in which the predicted mode was obtained using the equations derived for the case reinforcing with normal AFRP sheets. From this table, it is confirmed that the predicted failure modes are correspond to the experimental results. That is to say, when M_y/M_u is larger than 0.7, the sheet will be debonded after reaching compressive failure of concrete and when M_y/M_u is less than 0.7, the sheet will be debonded before reaching compressive failure of concrete.

Table 1 List of specimens.

Specimen	Designed pre-tension stress ratio* (%)	Actual pre-tension stress ratio* (%)	Introduced initial tensile strain (μ)
N	Non-strengthened		-
T0	0%	0%	
T20	20 % (51.7)	22.2% (57.5)	3,892
T40	40 % (104)	40.1% (104)	7,009
T50	50 % (129)	50.8 % (131)	8,883

*( ) pre-tension force (kN)

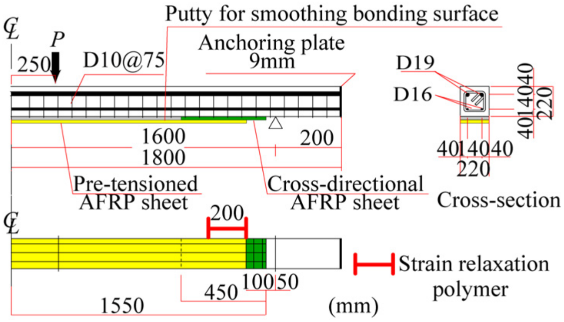

Fig.1 Layout of reinforcement and AFRP sheet.

Key words: RC beams, AFRP sheet, Flexural strengthening, Pre-tensioned bonding
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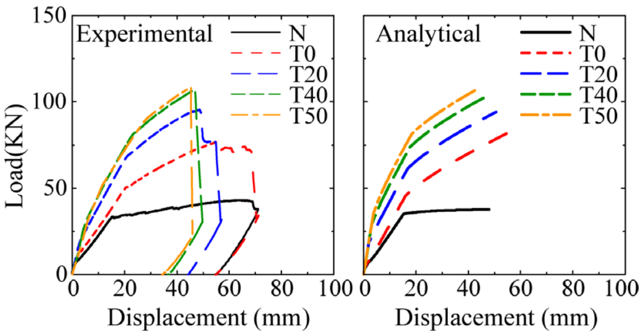

Fig. 2 Load-displacement relations of experimental and analytical results.

Table 2 Modes of failure.

Specimen	M_y/M_u*	Predicted failure mode	Experimental failure mode
T0	0.55	Sheet debonding before concrete crush	Sheet debonding before concrete crush
T20	0.65		Sheet debonding after concrete crush
T40	0.72	Sheet debonding after concrete crush	Sheet debonding after concrete crush
T50	0.76	Sheet rupture after concrete crush	Sheet rupture after concrete crush

*M_y and M_u are analytical yielding and ultimate moments

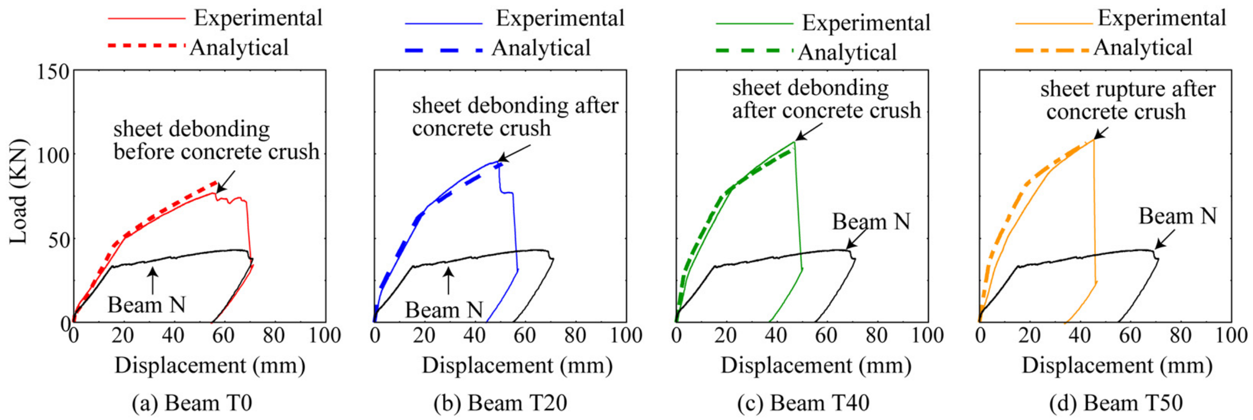

Fig. 3 Comparisons of load-displacement relations between experimental and analytical results.

3.2 Strain distribution

Figure 4 shows the comparisons of axial strain distributions of the AFRP sheet at the ultimate state between the experimental and numerical analysis results, in which the ultimate state was evaluated by numerical analysis. From this figure, it is observed that the numerical analysis results are in good agreement with the experimental ones for Beams T40/50. However, the numerical analysis results for Beams T0/20 cannot follow the experimental ones because the sheet was debonded before reaching compressive failure of concrete.

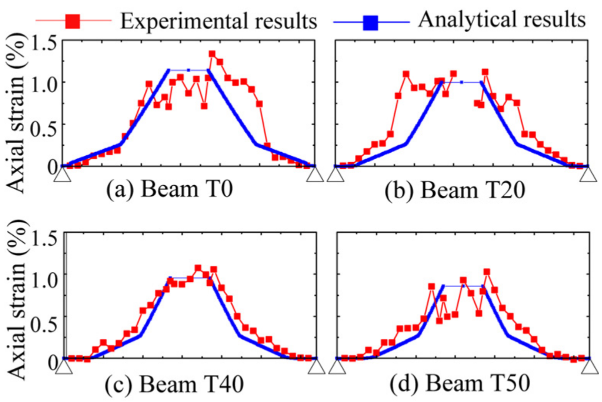

Fig. 4 Comparison of strain distributions of AFRP sheet.

4. Conclusions

1) Cracking load, yielding load and ultimate load can be increased considerably by increasing pre-tension force introduced to AFRP sheet bonded to RC beams;
2) Sheet debonding may be restrained by controlling introduced pre-tension force to AFRP sheet; and
3) Prediction equation for failure mode proposed on the basis of the experimental results for RC beams reinforced with normal AFRP sheet may be applied for flexural reinforced RC beams with pre-tensioned AFRP sheets.