LOADING TESTS OF PC BEAMS REINFORCED WITH CFS SUBJECTED TO TORSION

WASEDA University Civil & Environment Division JSCE member Haiming HE＆Akihito MASUDA
WASEDA University Civil & Environment Division JSCE member Osamu KIYOMIYA

1. INTRODUCTION It is important for the problem of torsion such as the large-sized gravity type structures and PC segment type immersed tunnel which are subjected to non-uniformed subsidence of soft ground, the floating type structures which are applied by wave force from slant direction and the pile type structures which receive eccentric load by an earthquake or loading of a vessel in recent years. On the other hand, as the one type of the reinforcement method, the application of the carbon fiber sheets (CFS) to improve the capacity of civil structures especially in concrete elements, creates a great issue in the field of civil engineering.

2. EXPERIMENTS Static loading tests of pure torsion were carried out in order to investigate basic properties of torsion and mechanical behaviours, and reinforcement effect of different type of reinforcement method by CFS. The loading tests are performed on PC beams and PC beams strengthened with CFS with square cross section on condition that one end is fixed and the other end is applied by torsion. The list of test specimens is presented in **Table 1.** The dimensions and outline of the specimens are shown in **Fig. 1** and **Fig.2**.

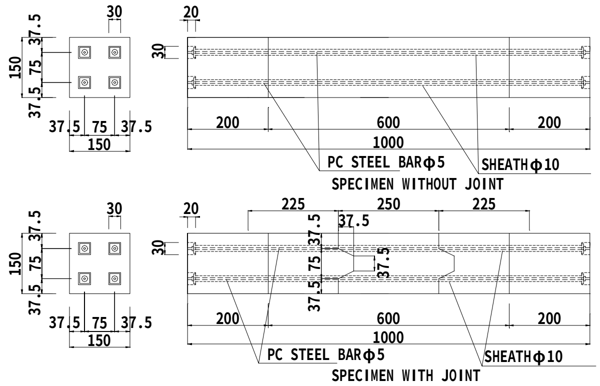

Fig. 1 Dimensions and basic structure Specimens of the Test series 1

Table 1 List of test specimens

Tests	Specimen	Joints	Reinforcement
Series 1	No.1	No	No
	No.2	Yes	No
Series 2	No.3	No	Complete reinforcement
	No.4	No	Zebra type reinforcement
	No.5	No	Zebra type(two sheets) reinforcement
	No.6	Yes	Complete reinforcement
	No.7	Yes	Complete reinforcement (two sheets)
	No.8	Yes	Zebra type reinforcement

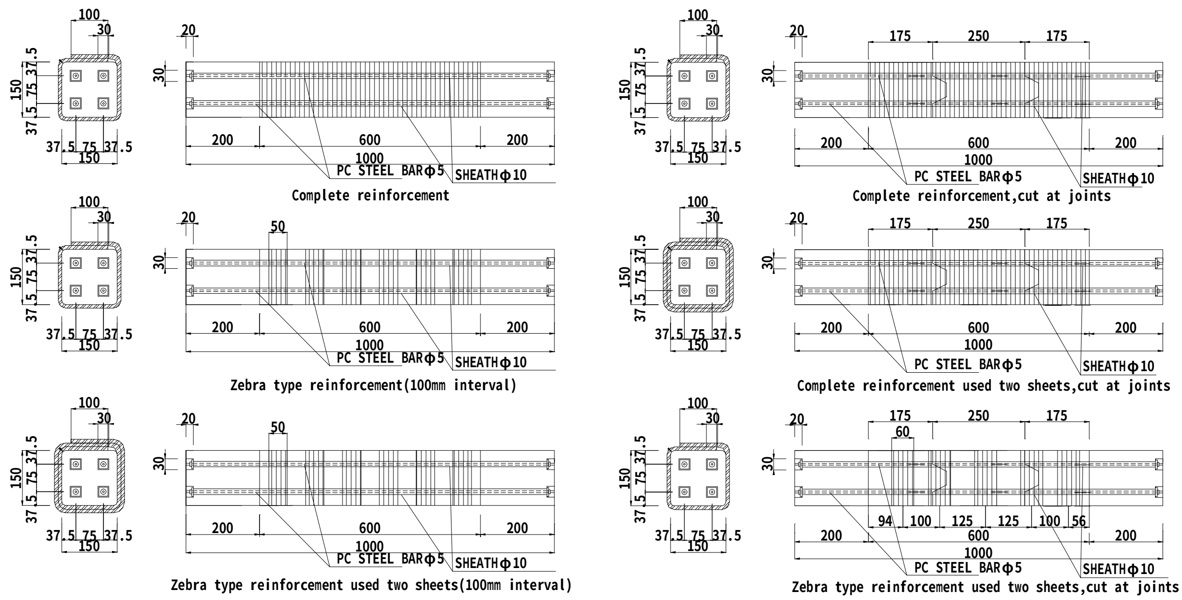

Fig. 2 Dimensions and reinforcement arrangement specimens of the Test series 2

3. EXPERIMENTAL RESULTS **Table 2** shows the results of the loading tests.

KEYWORDS: carbon fiber sheet (CFS), prestressed concrete beam, torsion behavior, static loading test
ADDRESS: 〒169-8555 51 building Waseda University Ohkubo 3-4-1 Shinjyuku, Tokyo TEL&FAX: 03-5286-3852

Table 2 The list of test results

Specimen	No.1	No.2	No.3	No.4	No.5	No.6	No.7	No.8
Maximum load (kN・m)	3.08	1.60	6.03	5.29	4.87	3.11	4.30	3.37
Maximum angle of twist at maximum load (rad/m)	0.0073	0.0313	0.1856	0.0079	0.0071	0.0740	0.0202	0.0081
Initial torsion rigidity (kN・m^2)	578.29	307.86	786.13	824.47	836.21	274.86	395.43	551.38

3.1 Torsion rigidity Torque-rotation curves of test series 1 and test series 2 obtained from the loading tests are plotted in **Fig. 3** and **Fig. 4.** In test series 1, the general behaviors about No. 1 specimen were such that, initially linear elastic behavior at a low loading stage was observed, and it appears that rapid collapse after reaching peak load. In contrast to No. 1 specimen the general behaviors about No. 2 specimen with joints were difficult to describe. After torque reached 0.8 kN・m, the rigidity decreased to the maximum load and the maximum load was smaller than that of No.1 specimen. The influence of the crevice between junction and the fall of torsion rigidity by the crack at the junction part are mainly related to the decrease of both the rigidity and maximum load. In test series 2, the general behaviors about specimens without joints (No.3, No.4 and No.5) were similar to No.1 specimen at the first part of the curve. In second part of torque-rotation curve, specimens show the different behaviors due to the different type of reinforcement method. Torsion bearing capacity on the loading test of the No.3 specimen did not fall where the angle of twist even reaches 10 times or more than the point where the torque-rotation curve is flat. Torsion bearing capacity on the loading test of the No.3 and No.4 specimens fell a little after reaching the maximum load, then held the value of load, only angle of twist was increased. The general behaviors about specimens with joints (No.6, No.7 and No.8) were also similar to specimens without joints at the first part of the curve. In second part of torque-rotation curve, No.6 and No.7 specimen held the value of load, only angle of twist was increased While No.8 specimen rapid collapsed after the angle of twist reached to 0.15.

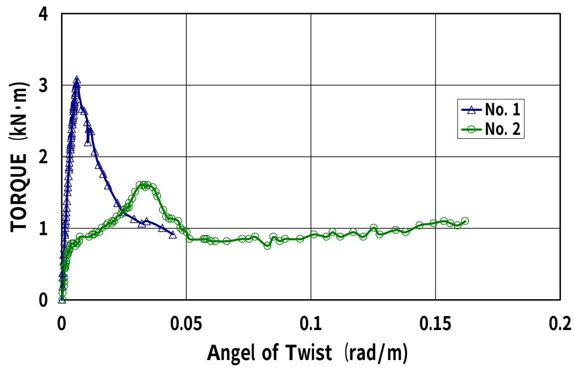

Fig. 3 Torque-rotation diagram of test series 1

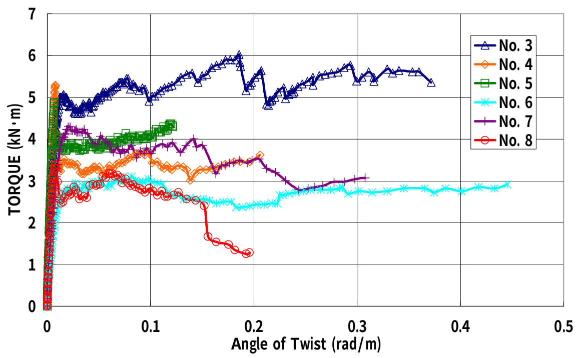

Fig. 4 Torque-rotation diagram of test series 2

3.2 Description of the destruction In test series 1, No. 1 specimen, the first crack was observed at the middle of the specimen and the load was near the maximum load, the angle of the crack is about 45°. With the increase of the load, the crack extended to the other sides of the specimen, eventually the crack was connected to four sides of specimen and the specimen was destroyed. In No. 2 specimen, the cracks occurred at the joints firstly and extended with the increase of the load. Eventually specimen was destroyed by the destruction of joints. In test series 2, the crack pattern of specimens without joint is similar to No.1 specimen, but simultaneously with occurrence of the first crack, many cracks were occurred through the other sides of specimen, the angle of the cracks are about 45°. The effect of reinforcement is large, all of the specimens without joint did not collapse at the loading tests. In specimens with joints, the cracks occurred at the joints firstly and extended with the increase of the load. Also the effect of reinforcement is large, No.6 and No.7 specimen did not collapse at the loading tests while No.8 specimen rapid collapsed after the angle of twist reached to 0.15.

4. CONCLUSIONS (1) With the reinforcement by CFS, bearing capacity of the specimen becomes much higher, especially in specimen with joint. (2) In specimen without joint, the more ratio of CFS used, the bearing capacity becomes more high. With the same ratio of CFS, complete reinforcement is better than zebra type reinforcement. (3) In specimen with joint, the reinforcement of the joint the most effective than any other parts.

REFERENCES He, H.M. et al.: Torsion Loading Test and Finite Element Method Analysis of PC Beam with Joint, Proceeding of the JCI, Vol. 25. No. 2, pp.709-714,2003