Experimental study on tensile behaviour of the crossing point in CFRP grid

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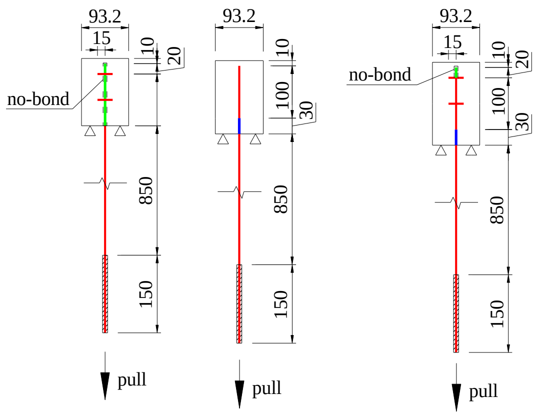
1. Introduction

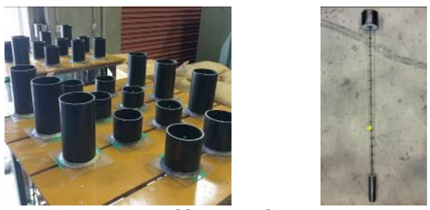
Retrofitting technique by using sprayed polymer mortar and Carbon Fiber Reinforced Plastic (CFRP) grids for concrete structures has been widely applied in Japan. As a mesh-type retrofitting material, if the crossing point in CFRP grid fractures before tensile failure of CFRP grid, the high tensile strength performance of CFRP grid will not be fully used. However, tensile behaviour of the crossing point has not been fully clarified yet. In this study, CR5@50 and CR8@50 are selected as the research objects and three kinds of pull-out tests are conducted. The main purpose is to obtain the minimum number of nodes in CFRP grid in order to make full use of tensile strength.

2. Experimental Programs

It is clarified that the anchorage actions of CFRP grid in the mortar are composed of the bond action of vertical bar and the resistant action of horizontal bar. In order to analyze the tensile behaviour of the crossing point in CFRP grid comprehensively, three types of anchorage conditions are conducted: (1) under no-bond condition with crossing section (NBW-type); (2) under bond condition without crossing section (BWO-type); (3) under bond condition with crossing section (BW-type). Different number of nodes (1, 2, 3) is applied to each anchorage condition. Three identical specimens were manufactured for each specimen design. The total number of specimen is 2 (grid type)×3 (number of nodes)×3 (anchorage condition)×3 (sample), which is equal to 54. **Figure 1** shows the dimension of specimens with two nodes. **Figure 2** shows the fabricating method of the specimen. To decrease the influence of inaccurate stress state of the mortar near the loading part, 30mm-length no-bond parts are conducted as shown in **Figure 1** (b) and (c).



(a) NBW-2 (b) BWO-2 (c) BW-2
Figure 1 Dimensions of specimens with two nodes



(a) Pouring mould (b) Representative specimen
Figure 2 Fabricating of the specimen

3. Results and discussion

3.1 Maximum load

Average maximum loads of all specimens are shown in **Table 1**.

Table 1 Maximum load of all specimens (kN)

Type		CR5@50	CR8@50
NBW	NBW-1	11.2	17.0
	NBW-2	18.1	28.3
	NBW-3	19.1	31.3
BWO	BWO-1	10.8	14.0
	BWO-2	23.5	29.5
	BWO-3	22.5	38.6
BW	BW-1	19.2	24.9
	BW-2	23.6	40.9
	BW-3	22.8	42.6

Note: "NBW-1" stands for the NBW-type specimen with one node. Others analogize.

3.2 Failure mode

Failure modes could be divided into three kinds (①,②,③), which are shown in **Figure 3**. **Table 2** shows the failure mode corresponding to each type of specimen.

① stands for the external CFRP gird still keep intact;
② stands for the break of the external CFRP grid;
③ stands for the smash of the external CFRP grid (It means the grid breaks into many parts).

It shows that the CFRP grid tends to break more and more seriously with the increasing number of nodes. When the maximum pull-out load is close to the maximum tensile load of CFRP grid, it will smash.

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① keep intact ② break ③ smash

Figure 3 Failure modes

Table 2 Failure mode of external CFRP grid

Type		CR5@50	CR8@50
NBW	NBW-1	①	①
	NBW-2	②	②
	NBW-3	②	②
BWO	BWO-1	①	①
	BWO-2	②	②
	BWO-3	③	③
BW	BW-1	②	②
	BW-2	②	②
	BW-3	③	③

3.3 Tensile strength utilization of CFRP grid

Define the tensile strength utilization α by equation (1).

$$\alpha = \frac{P_u}{T_{tg}} \times 100\% \qquad (1)$$

P_u—average maximum pull-out load for each specimen, as shown in **Table 1**;

T_{tg}—test maximum tensile load for CFRP grid, which is equal to 24.5 kN and 45.7 kN for CR5 and CR8 respectively.

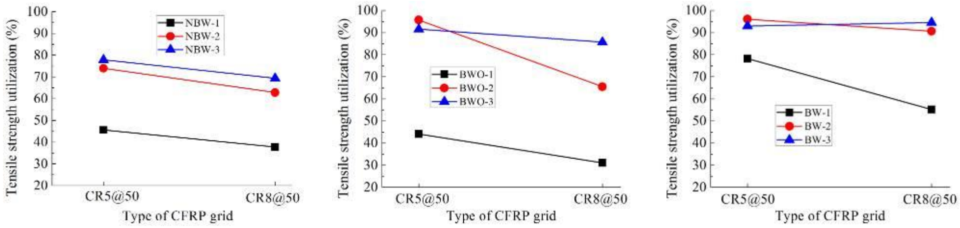
Table 3 Tensile strength utilization (%)

Type		CR5@50	CR8@50
NBW	NBW-1	45.6	37.8
	NBW-2	74.0	62.8
	NBW-3	77.9	69.4
BWO	BWO-1	44.1	31.1
	BWO-2	95.7	65.5
	BWO-3	91.6	85.7
BW	BW-1	78.2	55.2
	BW-2	96.1	90.8
	BW-3	93.2	94.5

Calculation results of tensile strength utilization are shown in **Table 3**. Considering the safety of practical engineering, it is regarded that when the tensile strength utilization is approximately not less than 70%, the tensile strength of CFRP grid is fully used (underlined value in **Table 3**).

It shows that in order to make full use of tensile strength of CFRP grid: (1) Under no-bond condition with crossing section (NBW) and bond condition without crossing section (BWO), it needs two nodes at least for CR5@50; while it needs three nodes at least for CR8@50. (2) Under bond condition with crossing section (BW), it needs one node for CR5@50; while it needs two nodes at least for CR8@50.

Theoretically, under the same anchorage condition, the tensile strength utilization ought to increase with the increasing number of nodes. But **Table 3** shows that under some conditions, the tensile strength utilization decreases with the increasing number of nodes (for CR5@50: BWO-2→BWO-3, BW-2→BW-3). Preliminary analysis shows that in this situation the tensile strength of CFRP grid has been fully used and this indicates that increasing the number of nodes couldn't improve the tensile capacity of pull-out specimens anymore. Therefore, when making comparative analysis of tensile strength utilization, discarding these meaningless data would be more reasonable. **Figure** 4 compares the tensile strength utilization corresponding to different CFRP grid types. It shows that the tensile strength utilization of CFRP grid decreases with the increasing of cross sectional area (CR5 (13.2mm^2)→CR8 (26.4mm^2).



(a) NBW-type (b) BWO-type (c) BW-type

Figure 4 Influence rules of CFRP grid type on the tensile strength utilization of CFRP grid

4. Conclusions

(1) In order to make full use of the tensile strength of CFRP grid: (a) Under no-bond condition with crossing section (NBW) and bond condition without crossing section (BWO), it needs two nodes at least for CR5@50; while it needs three nodes at least for CR8@50. (b) Under bond condition with crossing section (BW), it needs one node for CR5@50; while it needs two nodes at least for CR8@50.

(2) The tensile strength utilization of CFRP grid decreases with the increasing of cross sectional area.

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References: 1) Zhang, J., Ohno, K., et al. Mechanisms of bond failure between existing concrete and sprayed polymer cement mortar with CFRP grid by Acoustic Emission, Concrete 2013 (in CD-ROM), 2013, Gold Coast, Australia.