BOND BEHAVIOR BETWEEN CFRP PLATE AND CONCRETE UNDER MIXED-MODE

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1. INTRODUCTION

In case of flexurally strengthened concrete beams, the bond properties of FRP plate and concrete interface have been affected by a combination of fracture mode (Mode I and Mode II). The purpose of this study is to reappraisal the bond strength evaluation which has been evaluated in the previous study[1)] using the other four special double-face shear bond test specimen.

2. EXPERIMENTAL PROGRAM

2.1 Specimen

Basic concept of this study is to obtain bond strength directly using double shear bond specimen. A total of 4 specimens, which have the curved surface to connect two different cross sections to allow an initial angle, is tested. The detail of the specimen and the list are shown in Fig.1 and Table 1, respectively. The initial angle is disposed at the center of specimen which is 2° and 4°. The "pre-unbond" region (250mm) was set at the center in order to cause the combination of fracture mode easily. The other variable factor is concrete strength (target strength is 13.5MPa and 21MPa).

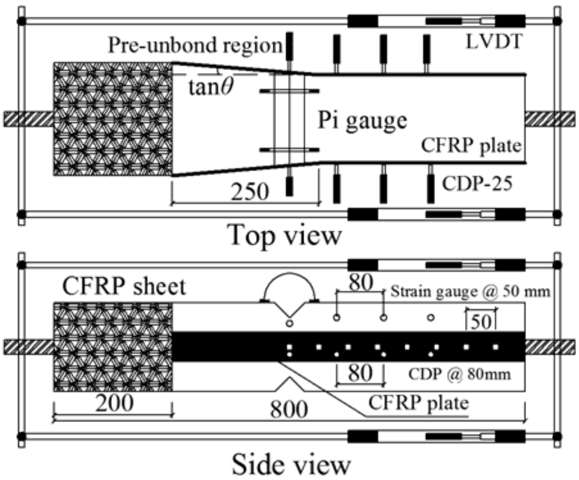

Fig.1 Detail of the specimen

Table 1 Specimen list

Specimen	Concrete strength (MPa)	Step height (mm)	Initial angle
C13HS-2-M	17.9	8.8	2°
C13HS-4-M			4°
C21HS-2-M	29.5	17.5	2°
C21HS-4-M			4°

Table 2 Experimental results list

Specimen	Bond strength (kN)	Calculated shear bond strength (kN)	Test / Calc.
C13HS-2-M	26.6	38.9	0.68
C13HS-4-M	18.3		0.47
C21HS-2-M	27.6	41.2	0.67
C21HS-4-M	19.7		0.48

C13HS-2-M C21HS-2-M

Fig.2 Typical failure surface

2.2 Loading and measurement

All the specimens were subjected to tensile force to cause shear and peeling debonding clearly at the interface of specimen. The measurement details were as the same as the previous experiment except measuring the peeling of the plate. In this test, the LVDTs were used to measure the displacement between plate and concrete surface which were instrumented at intervals 80 mm in each of the side as shown in Fig. 1.

3. TEST RESULTS AND DISCUSSIONS

3.1 Failure progress

Typical failure surfaces are shown in Fig.2. For all the specimens, it can be seen that the failure progress started from the "pre-unbond" region at the lower loading. The specimen C13HS-2-M's failure interface is debonded from concrete surface. However, the other specimens debonded from adhesive surface. Measured bond strength and calculated ones are listed in Table 2. The calculated strength is evaluated by previously proposed formula[2)] for comparing with the

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specimen without initial angle(shear bond strength).

3.2 Tensile load vs. crack width relation and Peeling distribution

Fig.3 shows the relationships of load versus crack width of the specimens in 13.5MPa. Regarding 4°'s specimen it can be considered that the first peak of the load appears when CFRP plate was debonding. After the sudden drop with the peeling angle decreasing, the load increases again. However in 2°'s situation, the combination of fracture mode was not so obviously considering, the debonding mechanism was similar to the shear mode. Fig. 4 shows the distributions of the peeling of CFRP plate as the transverse displacement differences between the concrete surface and the plate at the same position. This difference is considered to correspond to "floating" of CFRP plate from the concrete substrate. The floating exhibits some increases representing peeling off of the plate.

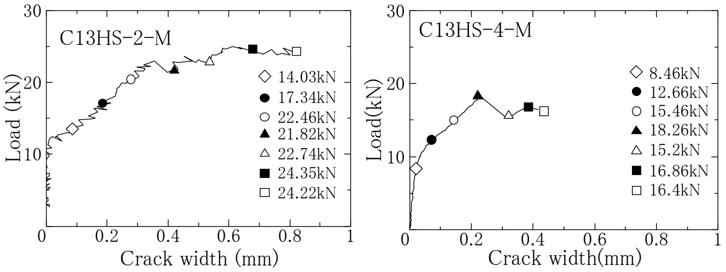

Fig.3 Load-Crack width

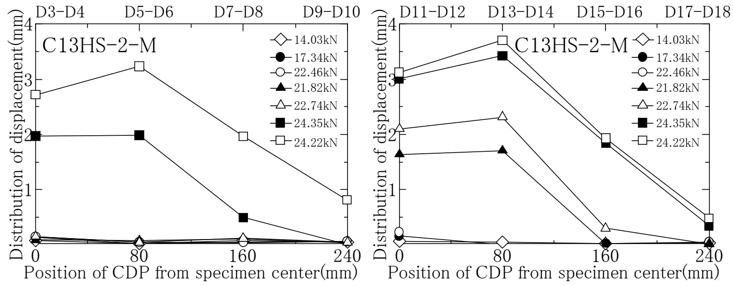

Fig.4 Peeling distribution

3.3 Bond strength evaluation

Fig.5 shows the ratio of tensile load P to the calculated shear bond strength P_{cal} vs. peeling angle relation. The dot × represents the results of previous study[1] and the other dots are obtained in this experiment. It can be found that the result of this experiment is consistent with the fitting line which is represented by $P/P_{cal} = 0.003\tan\theta^{-1.46}$ in previous study. The C21HS-4-M's data is not obtained due to sudden failure. Fig.6 plots the Eq. and calculated shear bond strength which varies by bond length. The intersection points give the bond strength under combination of fracture mode. Table 3 shows the calculated strength as the ratio to the shear bond strength. The ratio of experimental value to calculated ones varies from 0.73 to 1.00. The bond strength evaluation is also adaptable for this experiment.

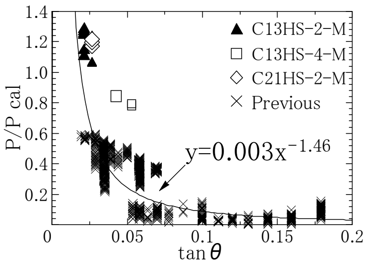

Fig.5 Tensile load-peeling angle

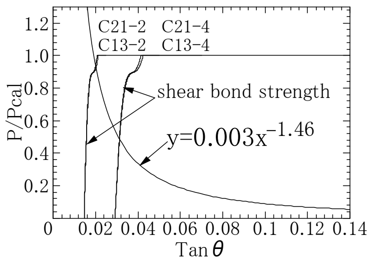

Fig.6 Bond strength diagram

Table 3 Bond strength evaluation

Specimen	Calculated shear bond strength (kN)	Ratio to the shear bond strength		Test / Calc.
		Test	Calc.	
C13HS-2-M	38.9	0.68	0.91	0.73
C13HS-4-M		0.47	0.48	0.98
C21HS-2-M	41.2	0.67	0.91	0.73
C21HS-4-M		0.48	0.48	1.00

4. CONCLUSIONS

It can be considered that the bond strength prediction which has been evaluated in previous study is available for the results of this experiment.

REFERENCES

1) Guan X., Zhang W., Kanakubo T., "Experimental study on bond behavior of CFRP plate in combination mode", Annual Meeting of JSCE Volume: 68th, Page: V-023. (in Japanese)

2) Matsunaga K., Kanakubo T., et al., "Study on Bond between CFRP Plate and Concrete", Summaries of Technical papers of Annual Meeting of Architectural Institute of Japan, C-2, pp.307-310, 2008 (in Japanese)