# Analytical Study on Bond Behavior between Fiber Sheets and Concrete

正会員　O　中場　和正[*1]
同　金久保 利之[*2]

## 1. Introduction

In order to study the bond behavior between concrete and polymer fibers, this paper employed an analytical method to quantify the maximum bond stress and the effective bond length using basic formulas of bond problems. The basic assumption for local bond stress versus slip relationship follows the prior study [1].

## 2. Specimen

The geometry of specimens is shown in Figure 1. The symmetry of the specimen provides the utilization of confinement sheet, and the analysis is done in one side of specimen. The notch is compelling the cut at the longitudinal center.

The parameters are the type of fiber (Carbon, Aramid and Glass fiber), and the concrete compressive strength as shown in Table 1.

## 3. Analysis and Results

The basic equation of bond problems is:

$$\frac{d^2 s_x}{dx^2} = b\left(\frac{1}{E_f A_f} + \frac{1}{E_m A_m}\right)\tau_x$$

It is obtained from an equilibrium of forces in specimen, where $S_x$ is the relative displacement between sheet and epoxy's layer / concrete / steel bar, $dx$ is an infinitesimal section of longitudinal axis, $x$, from the center of the specimen. $E_f$ is elastic modulus of sheet, $A_f$ is section area of sheet, $E_m$ is the equivalent elastic modulus of the part compounded of epoxy's layer, concrete and steel bar. $A_m$ is the sum of epoxy, concrete and steel bar transversal area.

The important step to understand the bond behavior is to have an assumption for local bond stress versus slip relationship, $\tau_x$.. The relationship used in this study can be approximately expressed as a bond stress-relative displacement bilinear relation. The Figure 2 shows the bond stress – relative slip relation ( τ - s model) [1]. The maximum local bond stress ( $\tau_y$) is equal to 4.13 MPa, the slip at maximum bond stress ($s_y$) is 0.0105 mm,

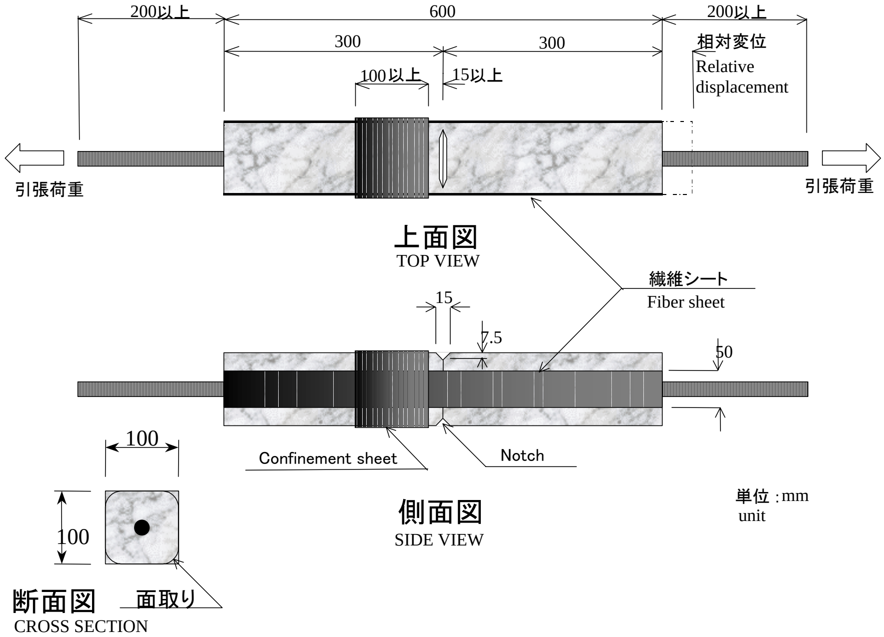


Fig. 1　Test specimen

Table 1　Data for Analysis

| Concrete | Identification | Sheet | | $E_f$ (GPa) | Thickness (mm) |
|---|---|---|---|---|---|
| | | Type | Weight (g/m²) | | |
| 20MPa Ec=22,000 MPa | C2-HCF | High Stiffness CF | 300 | 390 | 0.165 |
| | C2-SCFL | Carbon Fiber | 150 | 230 | 0.083 |
| | C2-SCF | | 300 | | 0.167 |
| | C2-SCFH | | 600 | | 0.334 |
| | C2-GLF | Glass | 300 | 85 | 0.118 |
| | C2-ARF | Aramid Fiber | 280 | 110 | 0.193 |
| 50MPa Ec=30,000 MPa | C5-HCF | High Stiffness CF | 300 | 390 | 0.165 |
| | C5-SCFL | Carbon Fiber | 150 | 230 | 0.083 |
| | C5-SCF | | 300 | | 0.167 |
| | C5-SCFH | | 600 | | 0.334 |
| | C5-GLF | Glass | 300 | 85 | 0.118 |
| | C5-ARF | Aramid Fiber | 280 | 110 | 0.193 |

Analytical Study on Bond Behavior between Concrete and Carbon, Aramid, and Glass Fiber Sheets

*NAKABA Kasumassa and KANAKUBO Toshiyuki*

and the slip at ultimate is 0.1210 mm. The analysis is done by integration of the basic equation by computer calculation.

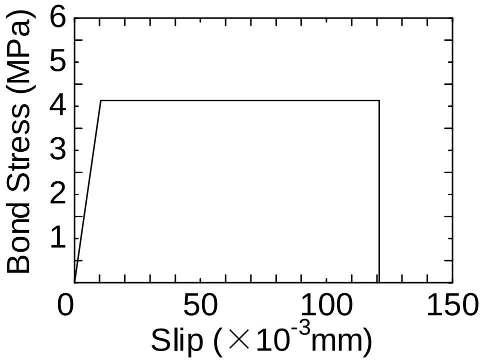


Fig. 2 Bond stress – slip model

Figure 3 shows the example of bond stress distribution and the lines express three steps of calculation. In the present analysis is supposed that after the specimen reaches the maximum load, the bond stress distribution keeps the shape and it is moving to the free end of sheet. The effective length is defined as two regions : the plastic ( $\tau_y$ = 4.13 MPa constant) and elastic region ( $\tau$ varying between 0.413 MPa and 4.13 MPa) as shown in Figure 3.

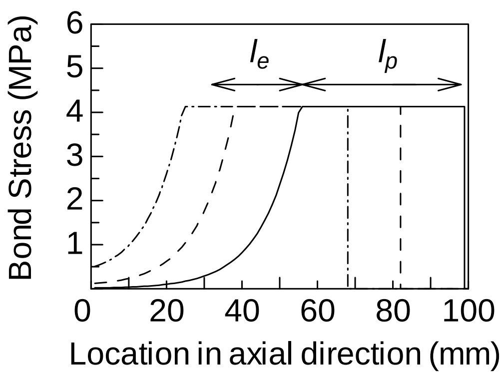


Fig. 3 Transition of bond stress

Table 2 shows the results of analysis. The total loads and effective lengths change by sheet types and weight. The loads and the lengths increase as the elastic modulus and weight of sheets also increase.

Figure 4 shows the stiffness of the sheets, elastic modulus times sectional area, versus total effective length ($l_t = l_e + l_p$) . Effective bond length varies from 30mm to 70mm.

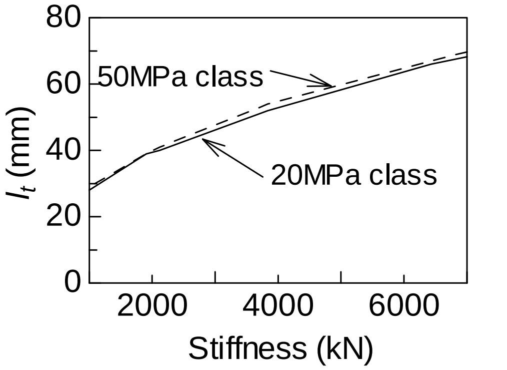


Fig . 4 Effective bond length – stiffness relationship

## 4. Conclusion

The present analysis provides the effective bond length for each combination type of fiber - concrete, by computer calculation.

## 5. Next Step

Only one relation between local bond stress and slip is used for the analysis. It will be verified experimentally. This relationship is especially important to understand the bond effectiveness.

**Reference:**


[1] Yuichi Sato, Kozo Kimura and Yoshiro Kobatake: Bond Behavior between CFRP Sheet and Concrete (Part 1) , 日本建築学会構造系論文集, 第 500 号, pp.75-82, 1997.10


Table 2 – Analysis of Results

| Identifi -cation | Total Load ($P$) (kN) | Slip at max. $P$ (mm) | Max. Slip (mm) | Effective Length (mm) | | |
|---|---|---|---|---|---|---|
| | | | | Elastic region $l_e$ | Plastic region $l_p$ | Total length $l_t$ |
| C2-HCF | 22.0 | 0.12 | 0.28 | 22 | 44 | 66 |
| C2-SCFL | 12.7 | 0.12 | 0.57 | 14 | 25 | 39 |
| C2-SCF | 17.5 | 0.12 | 0.38 | 18 | 34 | 52 |
| C2-SCFH | 23.8 | 0.12 | 0.26 | 23 | 48 | 71 |
| C2-GLF | 9.4 | 0.19 | 0.83 | 10 | 18 | 28 |
| C2-ARF | 13.4 | 0.12 | 0.54 | 14 | 26 | 40 |
| C5-HCF | 22.5 | 0.12 | 0.28 | 23 | 44 | 67 |
| C5-SCFL | 12.8 | 0.12 | 0.58 | 14 | 25 | 39 |
| C5-SCF | 17.8 | 0.12 | 0.38 | 19 | 35 | 54 |
| C5-SCFH | 24.3 | 0.12 | 0.26 | 25 | 48 | 73 |
| C5-GLF | 9.5 | 0.18 | 0.83 | 11 | 18 | 29 |
| C5-ARF | 13.5 | 0.13 | 0.54 | 15 | 26 | 41 |


*1 筑波大学大学院生 Graduate Program, University of Tsukuba

*2 筑波大学機能工学系 Institute of Engineering Mechanics and Systems, University of Tsukuba