Shear-bond behavior of Fiber Reinforced Polymer (FRP) rods and sheets

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**Background**

- **External reinforcing** is a technology widely used to enhance the capacity of reinforced concrete members.

- **Fiber Reinforced Plastics (FRP)** offer a variety of products, including sheets and rods.

![FRP sheet](image1.png)

![Attached FRP](image2.png)

![FRP rod](image3.png)

*Surakarta, 11-12 July 2018*
The Main Problem

- **The bond** between the FRP and concrete is of major importance to the performance of the composite material.
- Which of the *two materials provides the best solution?*
- How does their *mode of failure differ* from each other? The possible modes of failure are:
  1. Failure of the FRP material
  2. Concrete rupture
  3. Bond failure in the ITZ; in the ITZ between the FRP and epoxy, or between the concrete and the epoxy resin

- The mode of failure is a *function of concrete, FRP and epoxy resin material properties*, the application techniques, the surface roughness and the structural element’s characteristics
Research Objective

- When in bending, the bond response is distinguished into the shear and normal stress behavior.

**Element in bending**

- Concrete in flexural tension
- Bond in axial-compression
- Bond in tensile-shear
- FRP

**Interface strain responses**

- Concrete
- External reinforcement

**Shar and normal stresses**
Research Work

- The experimental test evaluated the bond response of FRP sheets and rods in pure shear.

Size in mm

![FRP rod test set-up]
FRP sheet test set-up
Results

Failure Modes

- FRP sheets. Two failure modes were observed:

1. Concrete shear-tension

2. Debonding in the interface between the epoxy and the concrete, only detected in the “untreated concrete surfaces”
- **FRP rods.** Two failure modes were observed:

  1. Concrete shear-tension

  2. Debonding in the interface between the epoxy and the rod, only detected in the rods with an embedment *less than the ACI 440-08 required depth*
Evaluation of Concrete Fracture Plane

(a) Cross section

- FRP length
- Bonded length
- FRP ITZ
- Unbonded length
- $\frac{1}{2}P$
- Vertical fracture angle $\alpha$
- Fracture envelope

(b) Plan view

- Fracture envelope
- Unbonded area
- $\frac{1}{2}P$
- Horizontal fracture angle $\theta$

<table>
<thead>
<tr>
<th></th>
<th>Fracture Angle</th>
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<tbody>
<tr>
<td></td>
<td>Vertical $\alpha$</td>
</tr>
<tr>
<td>Sheet</td>
<td>$5^0$</td>
</tr>
<tr>
<td>Rod</td>
<td>$24^0$</td>
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Evaluation of Concrete Fracture Plane

Concrete shear failure, plan view

<table>
<thead>
<tr>
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<th>Fracture Angle</th>
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<tbody>
<tr>
<td>Sheet</td>
<td>Vertical $\alpha$</td>
</tr>
<tr>
<td></td>
<td>5$^\circ$</td>
</tr>
<tr>
<td>Rod</td>
<td>24$^\circ$</td>
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</tbody>
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In Retrospect

<table>
<thead>
<tr>
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<th>Ultimate load (kN)</th>
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<tr>
<td></td>
<td>Concrete failure</td>
</tr>
<tr>
<td>Sheet</td>
<td>40.0</td>
</tr>
<tr>
<td>Rod</td>
<td>26.5</td>
</tr>
</tbody>
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Conclusions

• The FRP sheets require additional treatment, beyond the advise of the FRP producer

• The quality of the FRP sheets bond is very dependent on the application technique

• The FRP rods need to be embedded in accordance to the ACI guidelines and half embedded rods should be avoided

• In practice, the rods are more easily applicable, since they require less preparation area, and reduce the use of resin

• The application of sheets, due to their large area, produces dust and noise pollution

• The ACI code on bond shear overestimates the ultimate stress for rods, but underestimates the values for sheets
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Bachelor student  
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Technician
MEMORANDUM OF UNDERSTANDING (MoU)
ON
JOINT RESEARCH
FOR
EXTERNAL REINFORCEMENT USING FIBER RODS, BEHAVIOR AND
CONFIGURATION

AUTHORIZED SIGNATURES:
Each party represents that the individuals signing this MoU have the authority to sign on
its behalf in the capacity indicated.

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Bond-shear Behavior of FRP Rods as a Function of Attachment Configuration

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ABSTRACT: The use of external reinforcement to improve or enhances the flexural capacity of a member depends on the transfer capacity, and the failure behavior of the composite between the reinforcement, the epoxy resin and the concrete. The most influencing factor is the bond-shear capacity between the rod and the epoxy, and the epoxy to the concrete. Fiber Reinforced Polymer (FRP) rods are the latest alternate for fulfilling the external reinforcement scheme. In the field, the mandated embedment depth as outlined by the ACI 440 code, could customary not be achieved since factors such as the depth of the concrete cover, and presence of stirrups limits the space. This study is aimed to evaluate the effect of FRP rod configurations with respect to the concrete surface, to the effectiveness of external reinforcement. The study looked into the bond-shear capacity as well as the mode of failure, influence by the rod attachment depth. It was shown that the embedment depth significantly influenced the failure mode, and therefore the strain transfer capacity from the concrete to the rods.

Keywords: bond-shear, FRP rods, embedment depth, mode of failure