Shear Bolt Couplers for Splicing FRP Bars

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Table of Contents

• Introduction

• FRP Material Properties

• Problem Statement

• Mechanical Splices
Introduction

Fiber-reinforced Polymer (FRP) bars

• Alternative to steel bars
• Corrosion resistant
• High durability
• Cost-effective
• ¼ the weight of steel

○ Glass FRP (GFRP)
○ Basalt FRP (BFRP)
○ Carbon FRP (CFRP)
○ Aramid FRP (AFRP)
FRP Material Properties

• **Anisotropic behavior**
  ✓ High tensile strength in the fiber direction
  ✓ Low transverse strength (resin dominated)

• **Linear elastic up to failure (no ductility)**
  ✓ Cannot be used in seismic areas (no plastic hinges)

• **Low modulus of elasticity**
  ✓ Higher tensile strength, but less stiff than steel
  ✓ Less confinement to concrete
  ✓ FRP-RC members have more deflection than steel-RC
Problem Statement

FRP Challenges

- No yielding before failure
- Low modulus of elasticity
- Low shear strength
- Cannot be bent on site
- Low bond strength
- Long development length
- **Splicing of FRP bars**
Splicing Methods

1. **Lap Splice**
   - Overlapping two parallel bars
   - Conventional method
   - Inexpensive
   - Simple installation

2. **Mechanical Splice**
   - Consisting of a coupling sleeve
   - Transferring the force directly
   - Best alternative when lap splice is not practical
Lap Splice Challenges

✓ FRP bars require longer lap lengths than steel
✓ Congestion at splice locations
✓ Depend on the surrounding concrete to transfer the force between bars
✓ Spacing of FRP reinforcement is not sufficient for lap splicing in some cases due to either high load demand or small crack width requirements
✓ Not permitted for FRP bars larger than No.10 according to ACI 440.1R
Mechanical Splice

Applications

✓ For bar-to-bar connections when the bar cannot be bent
✓ Where the spacing of the reinforcement is limited
✓ Where large bars are used in heavily RC members
✓ In construction joints for future repair
✓ In precast segmental construction
✓ In prestressed concrete construction or in post-tensioning ducts for splicing tendons
Knowledge Gap

- No requirements or guidelines are available in *ACI 440.1R* or *AASHTO GFRP*
- Lack of an efficient mechanical splice for FRP bars
- Limited experimental data
Mechanical Splices

Design codes: ACI 439.3R, ASTM A1034, ACI 318, ACI133, CT670
ACI-318 Requirements

- **Type 1 Mechanical Splice**
  - Where inelastic deformations are not expected from the earthquake
  - They are required to develop a minimum of $1.25f_y$ for steel bar
  - The locations of these mechanical splices are restricted
  - Can not resist the stress levels expected in yielding regions

- **Type 2 Mechanical Splice**
  - In elements subjected to inelastic cyclic responses caused by earthquake
  - They are required to develop the specified tensile strength of the spliced bar ($f_u$) to avoid a splice failure when the reinforcement is subjected to expected stress levels in yielding regions
  - Type 2 mechanical splices on Grade 60 reinforcement shall be permitted at any location

[ACI 318-19, 18.2.7 and 25.5.7]
Bolt Couplers for Steel Bars

- A coupling sleeve with shear head screws designed to shear off at a specified torque
- The bolts are indented into the surface of the steel bars
- Commercially available bolt couplers cannot be used for splicing FRP bars
Bolt Couplers for FRP Bars

- New bolt couplers for splicing FRP bars
- Bolts pass through the entire specimen
- Half specimen is considered

Note: Thread length is part of the test setup
Bolt Couplers for Splicing FRP Bars

FRP Bar
- No.8 GFRP bars
- Sand-coated GFRP bars
- Grade III

Bolt Coupler
- Uniform inner and outer diameters
- Two bolts
- Three bolts
- Four bolts
Pull-out Test

- Pull out tests on spliced GFRP bars with bolt couplers
- Investigate the load-displacement behavior
- Determine the failure mode
- Estimate the bearing strength of FRP
- Determine the strength of the coupler
Thank U

QUESTIONS?
COMMENTS?

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