# Shear Bolt Couplers for Splicing FRP Bars


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# 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)**

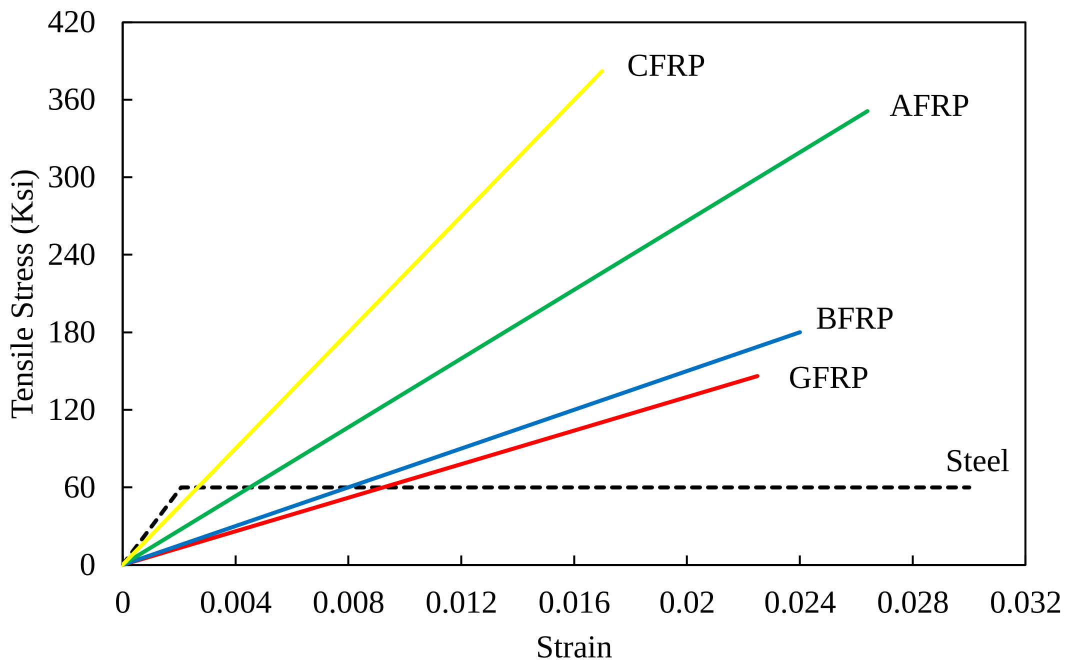
✓ Cannot be used in seismic areas (no plastic hinges)

- **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

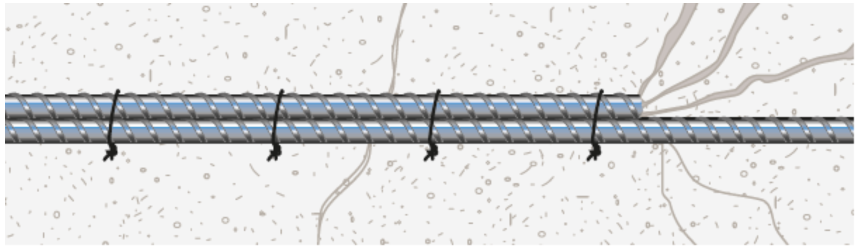
- No yielding before failure
- Low modulus of elasticity
- Low shear strength
- Cannot be bent on site
- Low bond strength
- Long development length
- **Splicing of FRP bars**

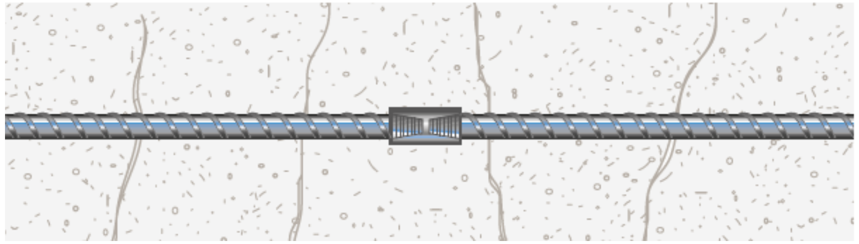
Deck of the Halls River Bridge in Homosassa (FL)

# Splicing Methods

## 1. Lap Splice

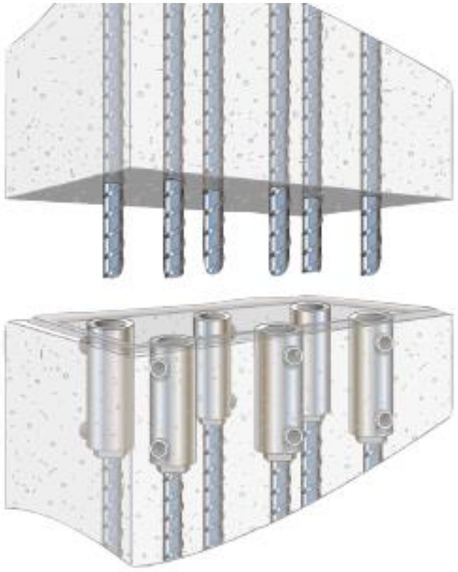
- ✓ Overlapping two parallel bars
- ✓ Conventional method
- ✓ Inexpensive
- ✓ Simple installation





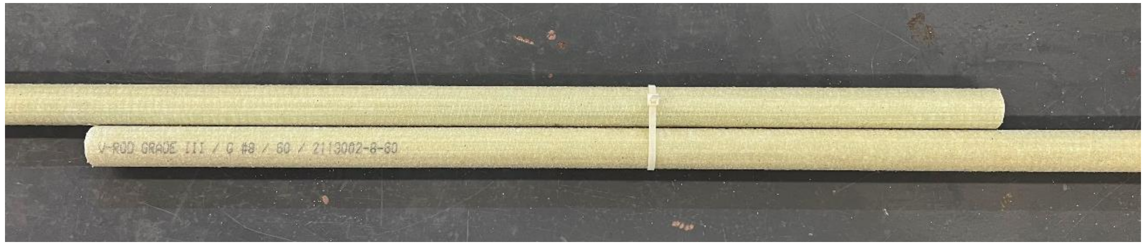
## 2. Mechanical Splice

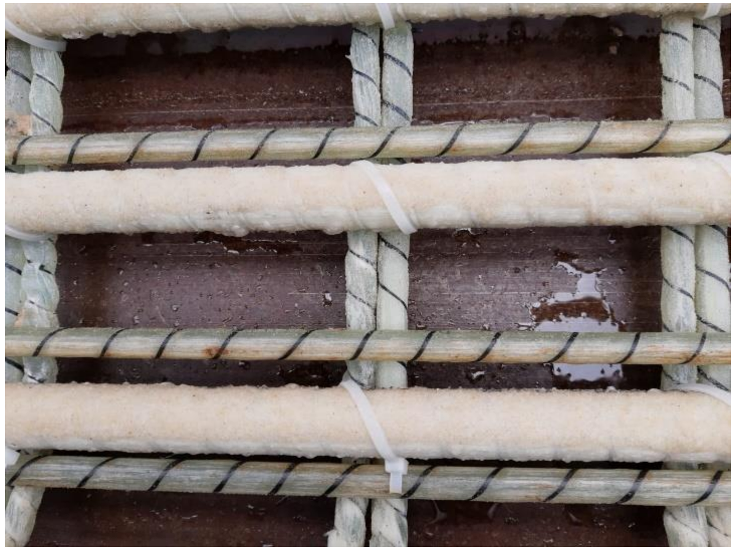
- ✓ Consisting of a coupling sleeve
- ✓ Transferring the force directly
- ✓ Best alternative when lap splice is not practical



# 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*



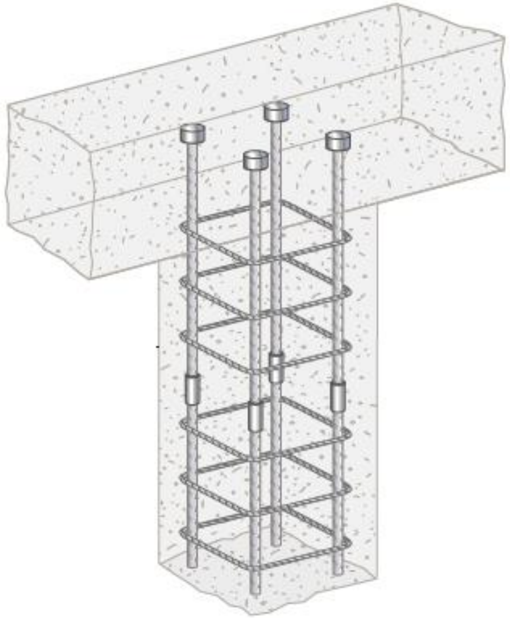


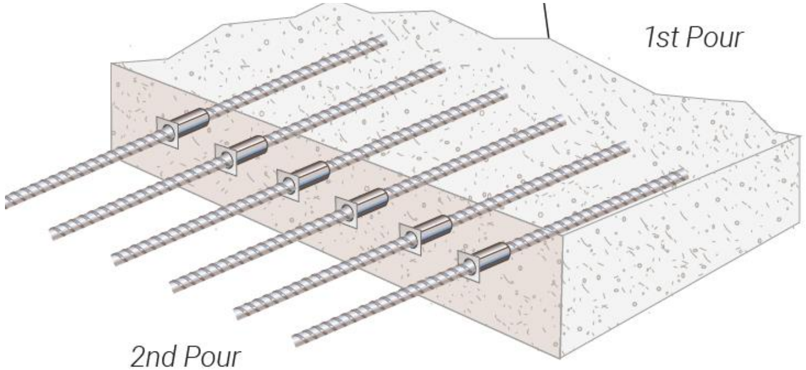
# Mechanical Splice

## 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

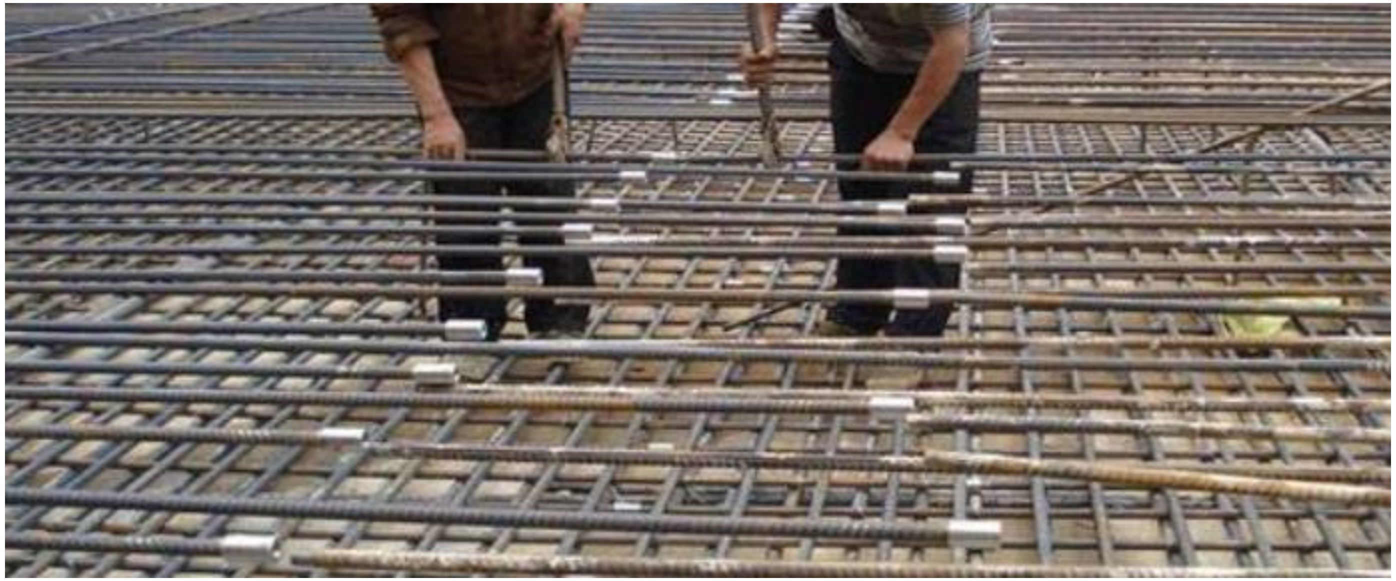
- ✓ In construction joints for future repair
- ✓ In precast segmental construction
- ✓ In prestressed concrete construction or in post-tensioning ducts for splicing tendons



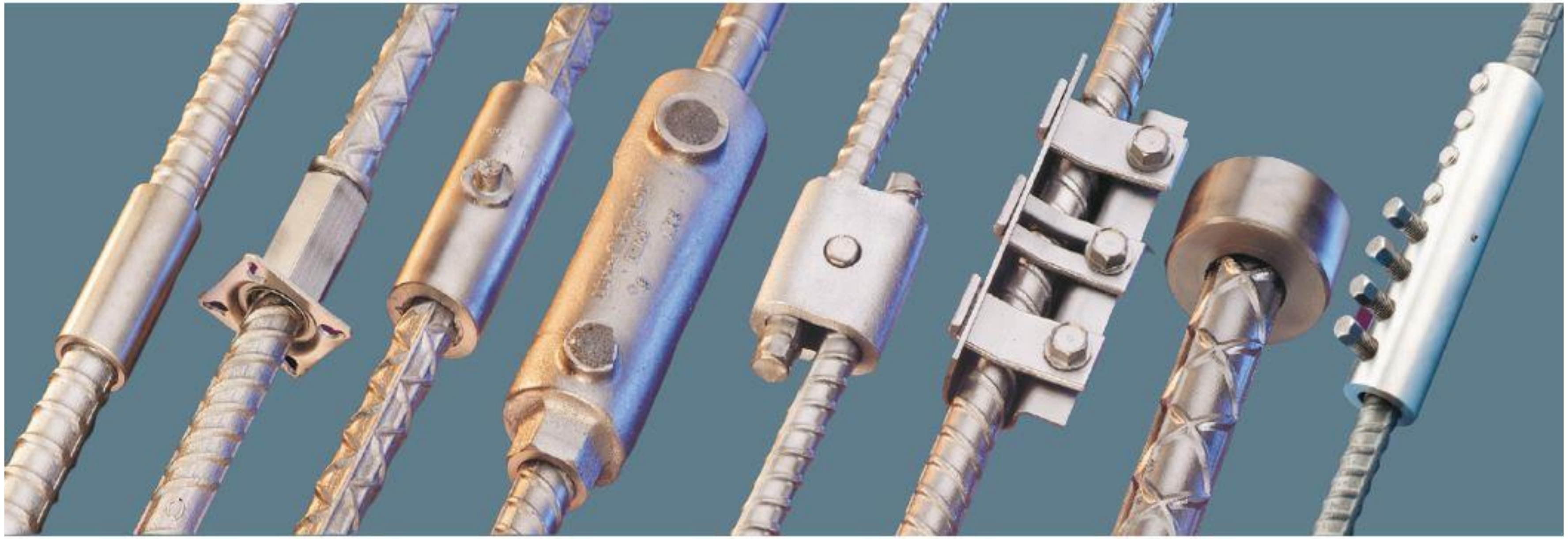


# Knowledge Gap

- 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, AC133, 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 1.25$f_y$ 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

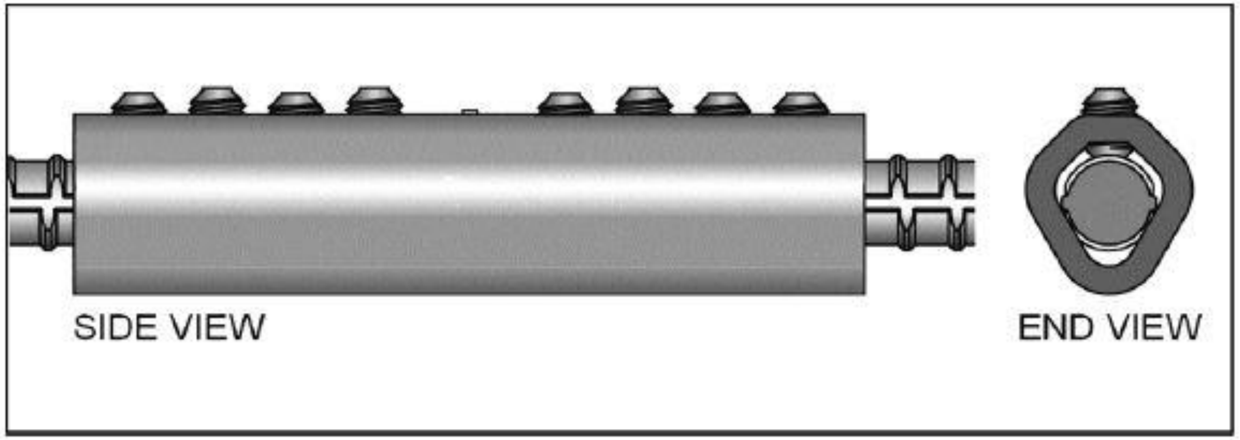
**[ACI 318-19, 18.2.7 and 25.5.7]**

# Bolt Couplers for Steel Bars

- A coupling sleeve with shear head screws designed to shear off at a specified torque

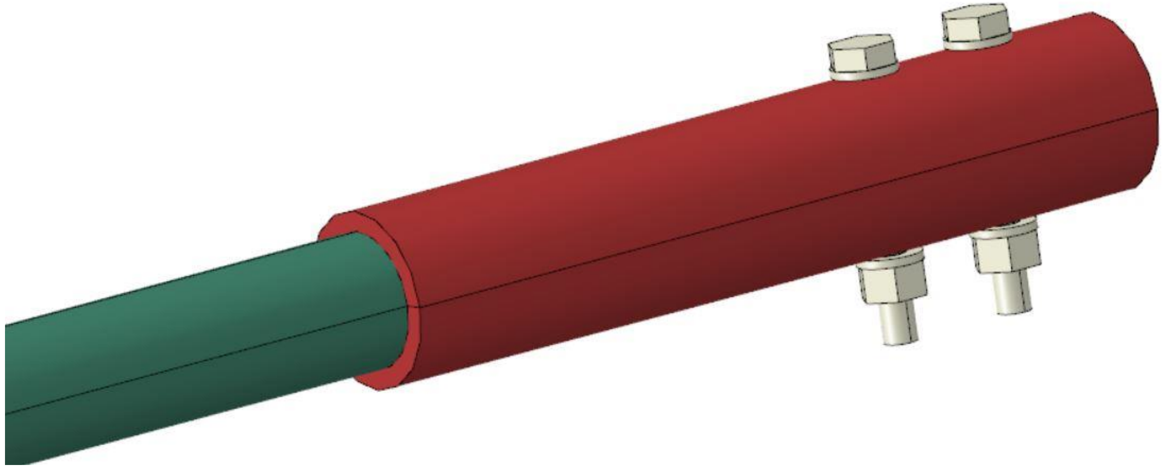
- The bolts are indented into the surface of the steel bars

- 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

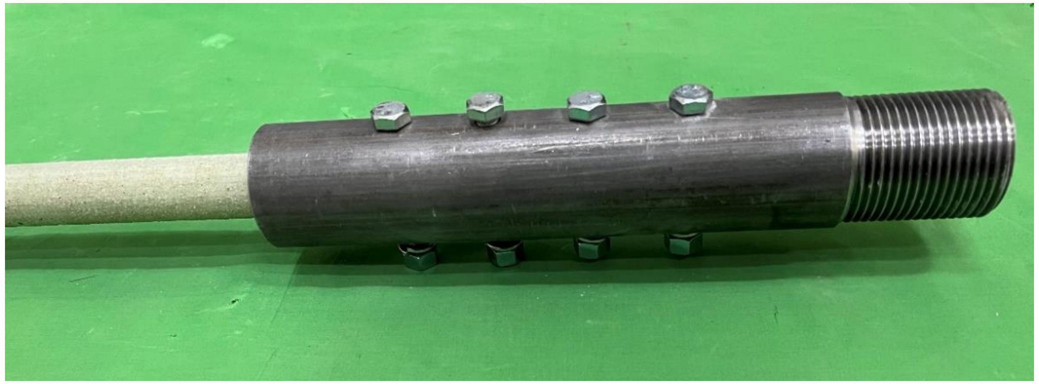
# Bolt Couplers for Splicing FRP Bars

## FRP Bar

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

## Bolt Coupler

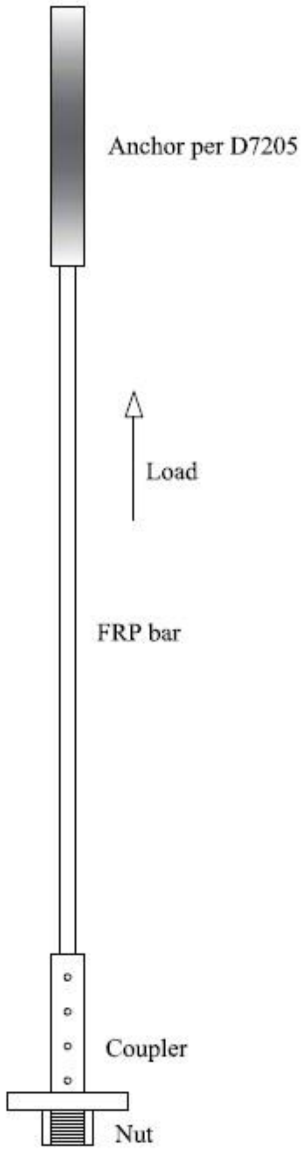
- Uniform inner and outer diameters
- Two bolts
- Three bolts
- Four bolts



# Research in Progress

## 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



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