Florida A&M University-Florida State University
College of Engineering

Department of Civil and Environmental Engineering

Bond-to-Concrete Characteristic of Basalt Fiber Reinforced Polymer Rebars

Presenter:
Tim Schneider

Raphael Kampmann, Tim Schneider, Srichand Telikapalli

Introduction

Overview

- Introduction
- Background
- Research Motivation
- Methodology
- Results and Discussion
- Closing Remarks

Introduction

Introduction

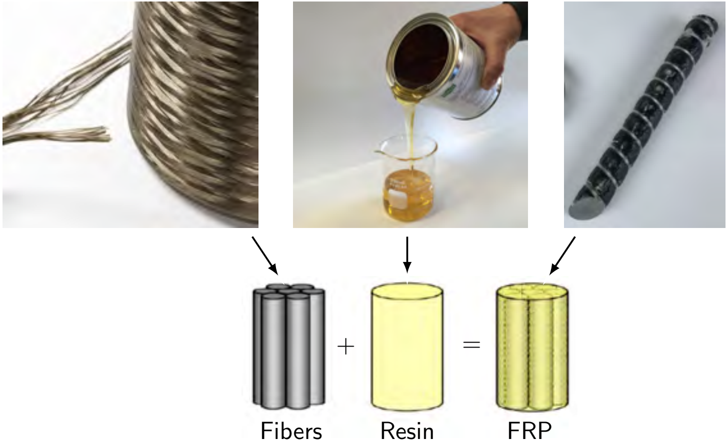
- Evaluation of alternative corrosion resistant reinforcement for concrete

- Most viable solution $\Rightarrow$ Fiber reinforced polymers (FRP) rebars

Background

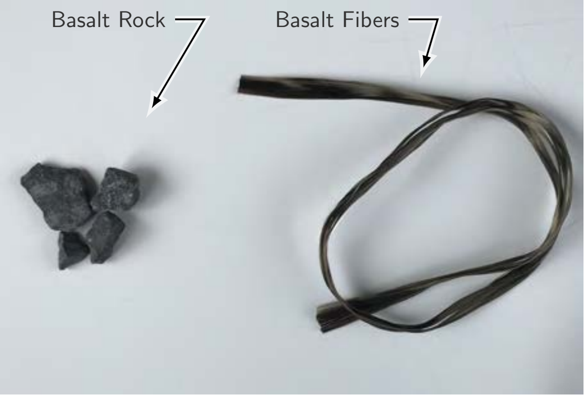
Background

Constituent Materials for FRP Rebars



Background

Basalt fiber production



- Igneous rock
- Processed into continuous fiber
- No additional ingredients

Background

Advantages of basalt FRP in structural engineering

- Compared to steel rebars
  - Lower weight
  - Three times the service life
  - 20 % to 30 % higher tensile strength
  - 35 % to 42 % lower modulus of elasticity

- Compared to glass FRP rebars
  - Higher tensile strength and higher modulus of elasticity

- Compared to carbon FRP and aramid FRP rebars
  - Lower price

Research Motivation

Research Motivation

Research significance

- Demand for more resilient structures continuous to increase
- Bond-to-concrete is an important mechanical characteristic of reinforced concrete
  - Guarantees proper stress transfer between rebar and concrete
- Bond-to-concrete performance of BFRP rebars not fully analyzed yet

Research Motivation

Problem statement

- A wide range of products available in market
- Diverse surface enhancements may lead to dissimilar bond-to-concrete behavior

Research Motivation

Research objectives

- Develop more knowledge about the bond-to-concrete performance BFRP rebars

- Integrate BFRP rebars in new design guidelines

Methodology

Methodology

Bond-to-concrete test — Overview BFRP rebars # 3

Type-A1

Type-A2

Type-B

Type-C

Type-D (steel)

Methodology

Bond-to-concrete test — Test matrix

# 3 Rebar	Surface Treatment	Resin Type
Type-A1	Sand coating	Epoxy (HE)
Type-A2	Sand coating	Epoxy (HP)
Type-B	Helical wraps & sand coating	Epoxy
Type-C	Sand coating	Vinyl ester
Type-D[1]	Surface lugs	Black steel

[1] Control group (values from manufacturer)

Methodology

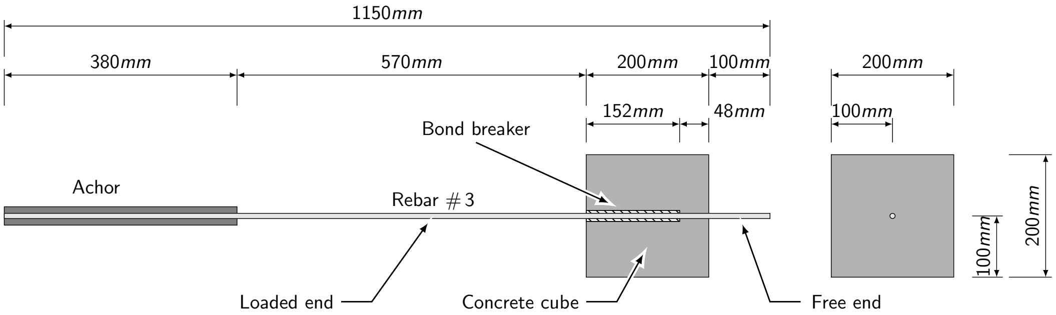
Test methods

- Bond-to-concrete strength
  - Pullout tests according to ASTM D7913
  - Concrete compressive strength
    - 6x12 Cylinders according to ASTM C39

Pullout test

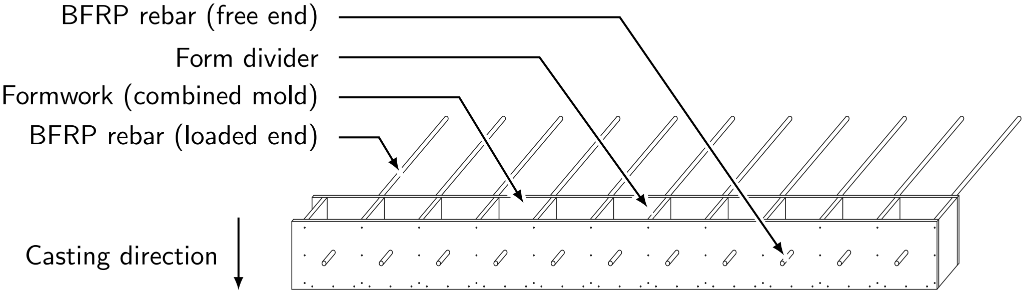
Methodology

Bond-to-concrete test — Specimen dimensions



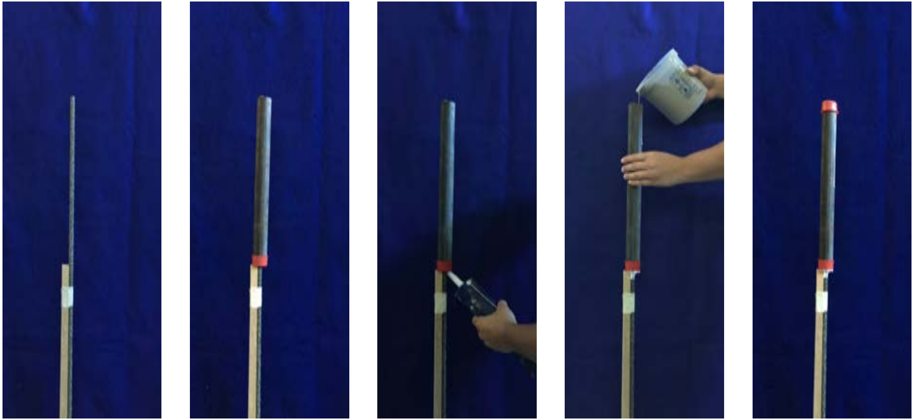
Methodology

Bond-to-concrete test — Casting of concrete



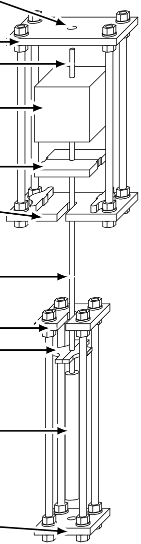
Methodology

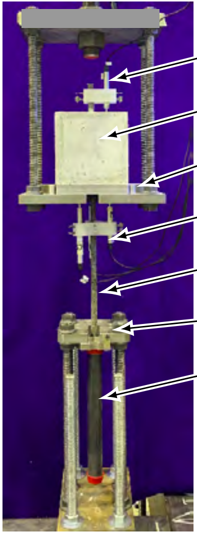
Bond-to-concrete test — Anchor installation



Methodology

Bond-to-concrete test — Test setup





Result and Discussion

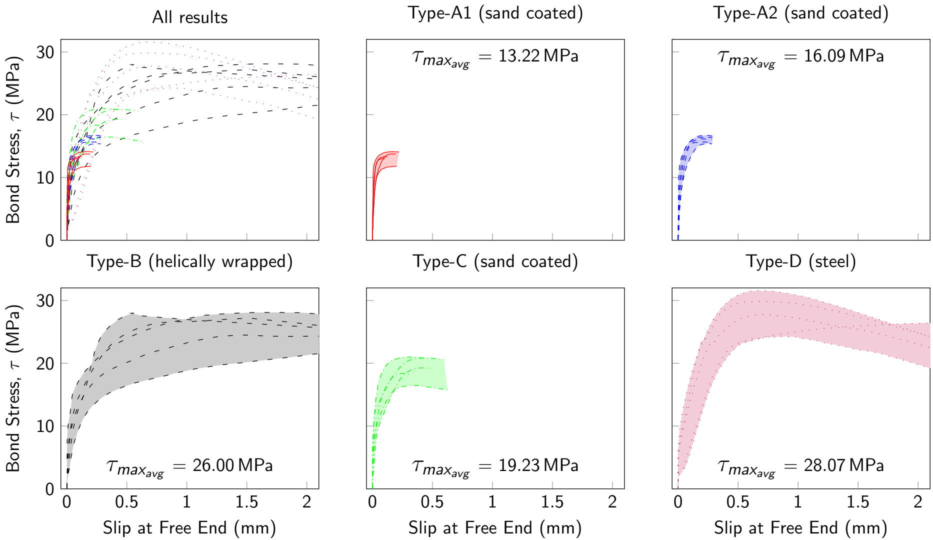
Result and Discussion

Concrete compressive strength — Statistical evaluation

- Mean compressive strength of 51.00 MPa (7400 psi)
- Standard deviation of 1.39 MPa (201 psi)
- Coefficient of variation of less than 2.7 %

Result and Discussion

Bond-to-concrete strength — Load-displacement behavior



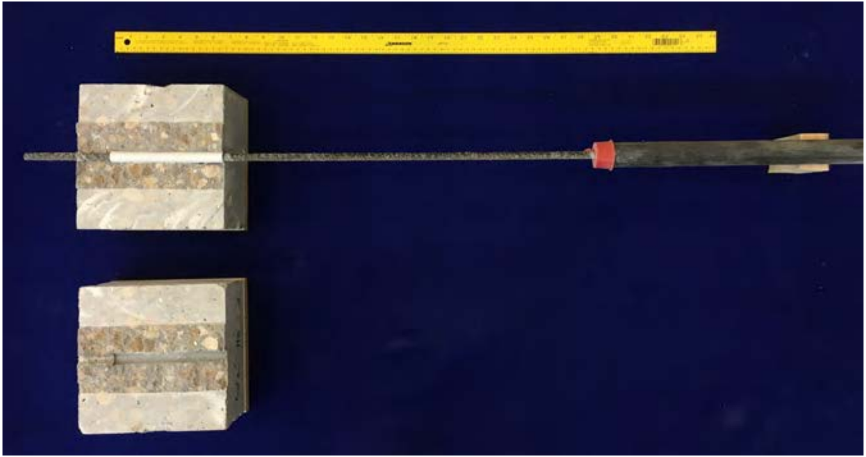
Result and Discussion

Bond-to-concrete strength — Statistical evaluation

Sample Group		Statistical Values								
		Imperial				Metric				
Rebar Type	Resin Type	$\wedge$ ksi	$\vee$ ksi	μ ksi	σ ksi	$\wedge$ MPa	$\vee$ MPa	μ MPa	σ MPa	CV %
A	HE	1.71	2.05	1.92	0.13	11.81	14.15	13.22	0.90	0.07
A	HP	2.24	2.43	2.33	0.08	15.41	16.74	16.09	0.54	0.03
B	Epoxy	3.20	4.08	3.77	0.38	22.08	28.15	26.00	2.64	0.10
C	VinylEster	2.39	3.05	2.79	0.27	16.49	21.04	19.23	1.89	0.10
D	Steel	3.53	4.59	4.07	0.41	24.33	31.65	28.07	2.85	0.10

Result and Discussion

Bond-to-concrete strength — Specimen failure



Result and Discussion

Bond-to-concrete strength — Specimen failure

Type-A1 Type-A2 Type-B Type-C Type-D (steel)

Result and Discussion

Bond-to-concrete strength — Analysis & discussion

- Concrete dust was observed for steel rebars only
  - Steel rebars $\Rightarrow$ Pullout strength limited by concrete properties
  - BFRP rebars $\Rightarrow$ Pullout strength limited by rebar properties

- Helically wrapped rebars were squeezed through concrete
  - Due to low transverse stiffness

- Delamination of sand coated rebars (without surface deformation)
  - Limited by resin shear strength

Result and Discussion

Bond-to-concrete strength — Analysis & discussion

- Bond behavior measurably affected by two aspects:
  1. Surface enhancement properties
  2. Resin type

- Deformed rebars (helically wrapped) provide additional interlocking
  - Bond performance similar to traditional steel rebars
  - May be preferred due to longevity of bond (e.g.: temperature variations)

Closing Remarks

Closing Remarks

Conclusions

- Steel rebars provided higher bond strength than (sand coated) BFRP rebars
- The pullout failure mechanism differs between BFRP and traditional steel rebars
- Surface enhancements highly influenced the bond-to-concrete behavior and performance
- Resin type impacted bond-to-concrete performance

Closing Remarks

Acknowledgment

- Florida Department of Transportation (FDOT)
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Closing Remarks

Questions ?

Raphael Kampmann
kampmann@eng.famu.fsu.edu

Tim Schneider
tim.schneider@fh-muenster.de