FIBER REINFORCED POLYMER (FRP) COMPOSITES REBAR

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Outline

- About ACMA
- Introduction
- FRP Materials
- FRP Bars
- Standards & Specifications
- Applications
- Summary

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About ACMA

- Formed in 1979
- World's largest composites trade association representir

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ACMA Industry Council

- **Mission** - Promote the use and growth of FRP reinforcement (rebar, tendons & grids) in concrete and masonry applications through development of quality procedures, industry specifications, performance standards, and field application guidelines.

FRP-RMC

FRP Rebar Manufacturers Council

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FRP-RMC Manufacturers

- BP Composites
- Composite Rebar Technologies, Inc.
- Hughes Brothers, Inc.
- Marshall Composite Technologies, Inc.
- Pultrall, Inc.

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Introduction

- The Problem - Corrosion
  - Corrosion and deterioration of steel reinforced concrete
  - Mitigation techniques - High costs to rehabilitate and remediate structures
  - Safety - Construction zones and detours
- The Solution – FRP Rebars
  - Non corrosive concrete reinforcement
  - Increase service life (durability)
  - Hundreds of applications in service in North America

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Traditional Approach to Corrosion Problems

- Reduce, Eliminate, or Negate the Current Flow of the Electrochemical Corrosion Cell Inherent With Steel Reinforced Concrete
  - ✓ Admixtures
  - ✓ Increase Concrete Cover
  - ✓ Efforts to reduce permeability & mitigate cracking - HPC
  - ✓ Alter Concrete Mix
  - ✓ Membranes & Overlays
  - ✓ Epoxy coated steel
  - ✓ Cathodic protection
  - ✓ Sacrificial anodes

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FRP Materials

Why are composites different?

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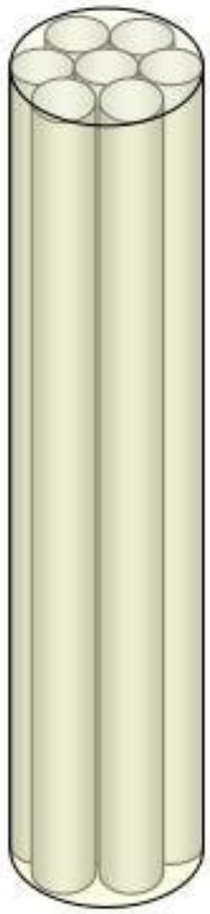
FRP Materials

Constituents

What is FRP?



Fibers

Provide strength and stiffness

Carbon, glass, aramid

Matrix

Protects and transfers load between fibers

Polyester, Epoxy, Vinyl Ester, Urethane

Fiber **Composite** **Matrix**

Creates a material with attributes superior to either component alone!

fibers **and** matrix both play critical roles in the composites material...

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What is different?

- FRP is Anisotropic
  - High strength in the direction of the fibers
  - This anisotropic behavior affects the shear strength, dowel action, and bond performance
- FRP does not exhibit yielding: the material is linear elastic until failure
  - Design should account for lack of ductility
  - Member does have substantial deformability

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Composites Features

- Impervious to chloride ion and chemical attack
- Tensile strength is greater that steel
- ¼ the weight of steel
- Transparent to magnetic fields and radar frequencies
- Electrically non-conductive
- Thermally non-conductive

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Where should FRP rebar be used?

- Any concrete member susceptible to corrosion by chloride ions or chemicals
- Any concrete member requiring non-ferrous reinforcement due to Electro-magnetic considerations
- As an alternative to epoxy, galvanized, or stainless steel rebars
- Where machinery will “consume” the reinforced member ie. Mining and tunneling
- Applications requiring Thermal non-conductivity

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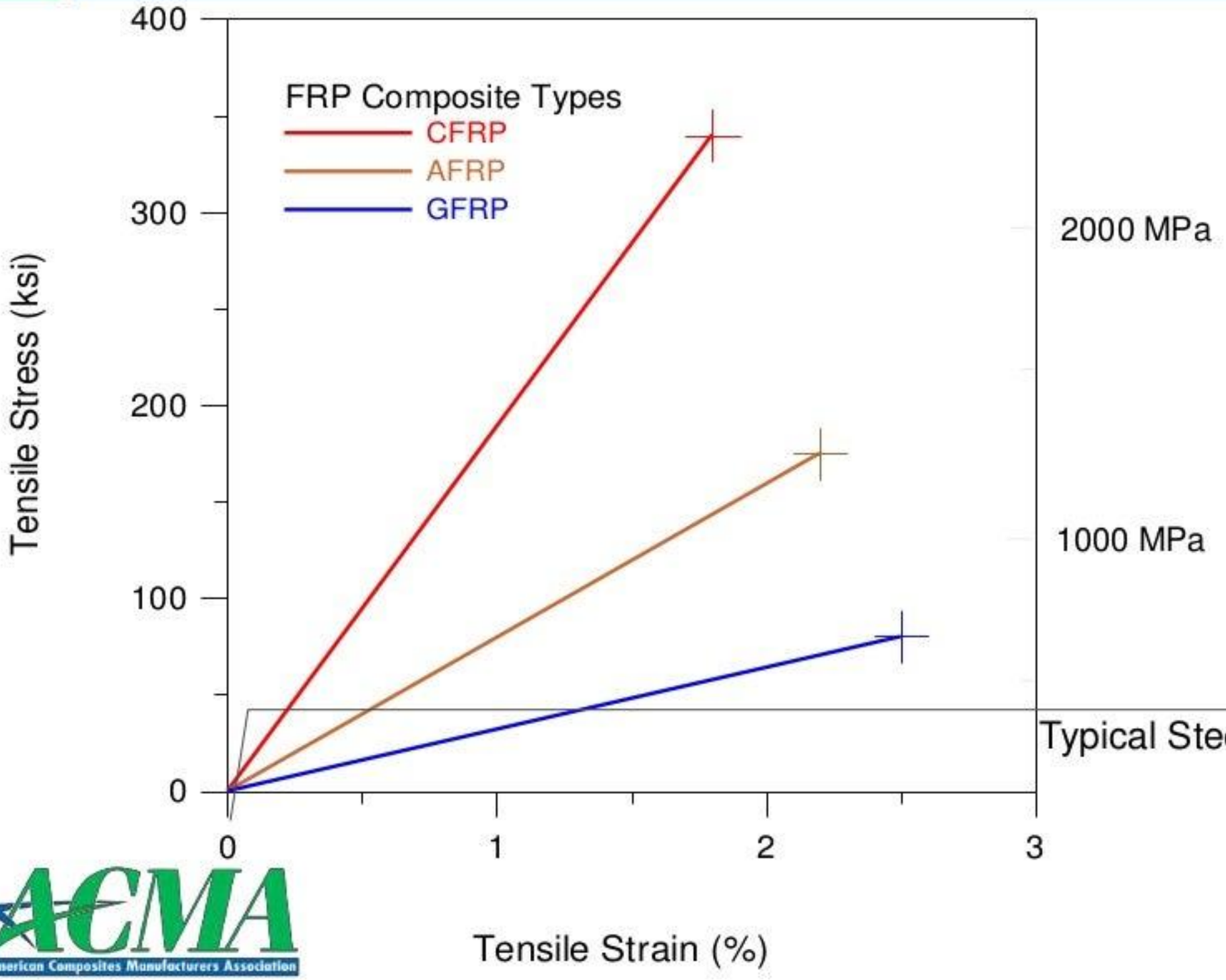
Tensile Stress-Strain Characteristics



- Linear elastic behavior to failure
- No yielding
- Higher Ultimate Strength
- Lower Strain at Failure

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FRP Properties

	Steel	GFRP	CFRP	AFRP
Yield Stress ksi (MPa)	40 - 75 (276 - 517)	N/A	N/A	N/A
Tensile Strength ksi (MPa)	70 - 100 (483 - 690)	70 - 230 (483 - 1600)	87 - 535 (600 - 3690)	250 - 368 (1720 - 2540)
Elastic Modulus X 10^3 ksi (MPa)	29 (200)	5.1 - 7.4 (35 - 51)	15.9 - 84 (120 - 580)	6.0 - 18.2 (41 - 125)
Yield Strain %	.14 - .25	N/A	N/A	N/A

Source: ACI 440.1R-06

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Factors Affecting Material Characteristics

- Type of fiber
- Fiber volume
- Type of resin
- Fiber orientation
- Quality control procedures during manufacturing
- Rate of curing
- Void content
- Service temperature

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Coefficient of Thermal Expansion

CTE (10^{-6} °F)

Material	Longitudinal Direction	Transverse
Concrete	4 ~ 6	4 ~ 6
Steel	6.5	6.5
GFRP	3.5 ~ 5.6	»12
CFRP	- 4 ~ 0	41 - 58
AFRP	- 3.3 ~ - 1.1	33 - 44

- Values of CTE differ between FRP materials and concrete.

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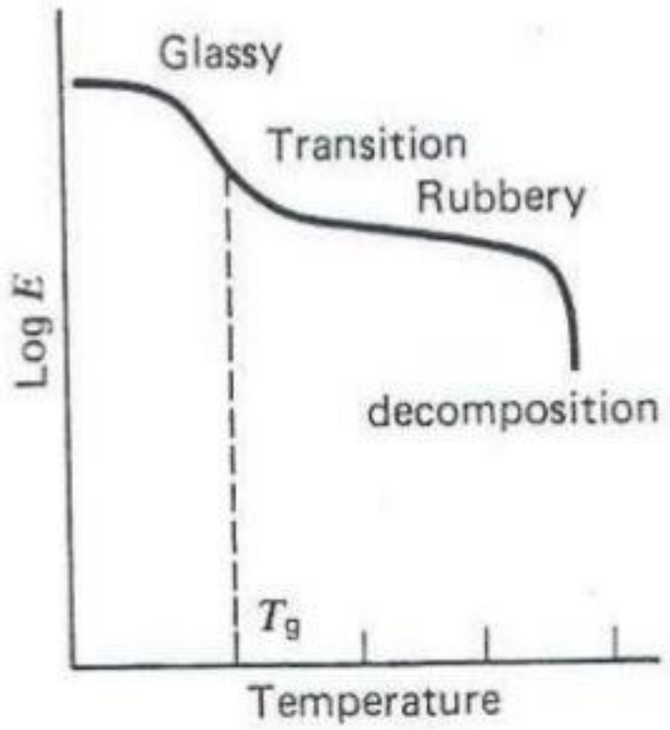
Effect of High Temperatures

- Resins will soften due to excessive heat
- The tensile, compressive, and shear properties of the resin diminish when temperatures approach the Glass Transition Temperature, T_g
- T_g values are approximately 250°F (120°C) for vinylester resins which are typically used with GFRP rebars
- T_g lowers as a result of moisture absorption



FRP bars

Looks are deceiving

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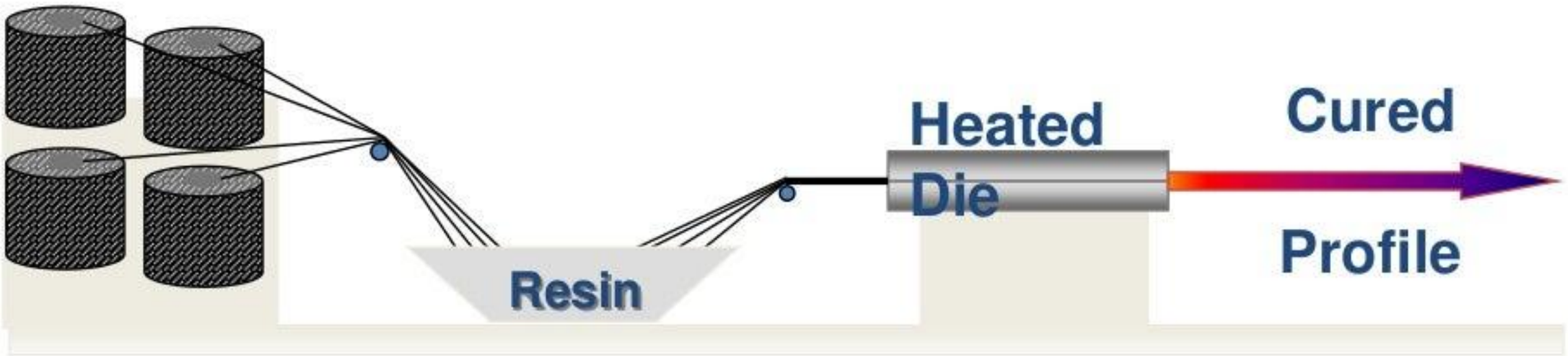
Pultrusion Process



Most products are manufactured with this process

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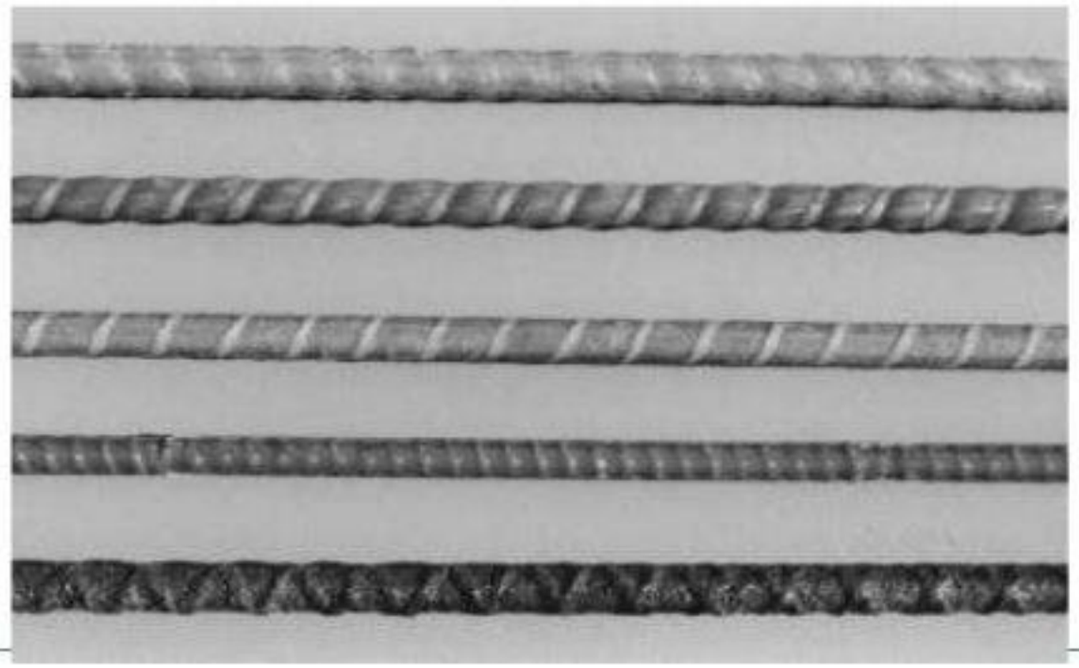
FRP Bar Types

- Materials
  - Glass/ vinylester
  - Carbon/ vinylester

- Forms
  - Solid



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