Composite Materials: Analysis and Design

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Chapter 1:

Introduction to Composite Materials

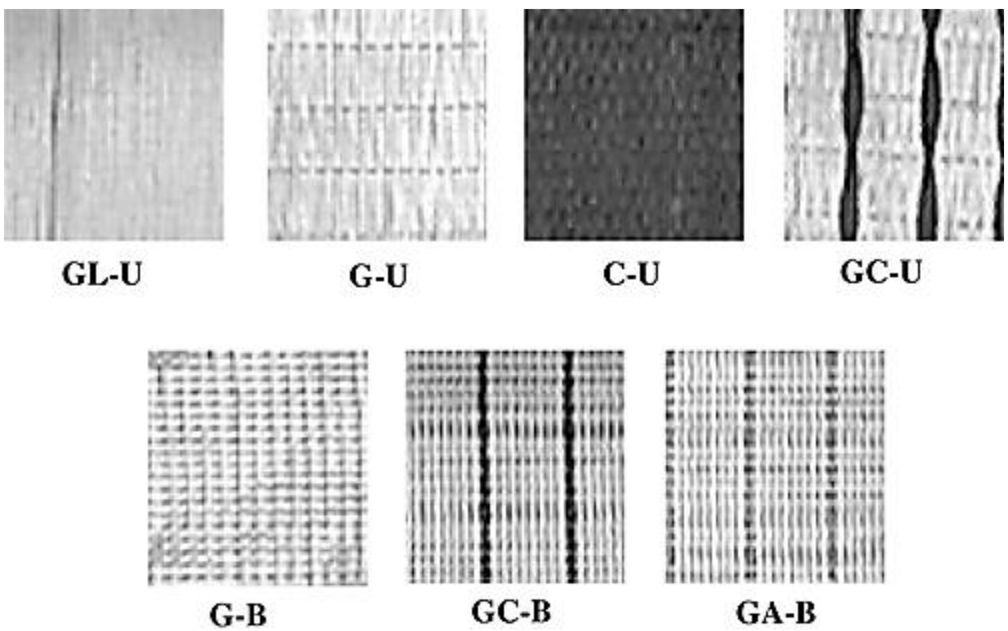
Chapter 1: Introduction

❑ Outline

- ✓ Definition of Composite Materials
- ✓ FRP Composite Constituent Materials
  - Fibers
  - Matrices
- ✓ Characteristics of FRP Materials
- ✓ Application of FRP Composites
- ✓ Type of Composites

Chapter 1: Introduction

- Environmental Effects on Mechanical Properties of FRP



Designation	Orientation	Fiber type
	Unidirectional	Glass
	Unidirectional	Glass
	Unidirectional	Carbon
	Unidirectional	Glass/ carbon
	Bidirectional	Glass
	Bidirectional	Glass/ carbon
	Bidirectional	Glass/ aramid

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- Envir. Effects on Mech. Properties of FRP

Designation	Temperature	Humidity	pH	ASTM*
W-S- ALK	Ambient	NA		C581
W-W-ALK	Ambient	NA		C581
W- NEUT	Ambient	NA		C581
W-S-ACID	Ambient	NA		C581
OCIEN	Ambient	NA		D1141
SOIL†	Ambient	NA		D3083

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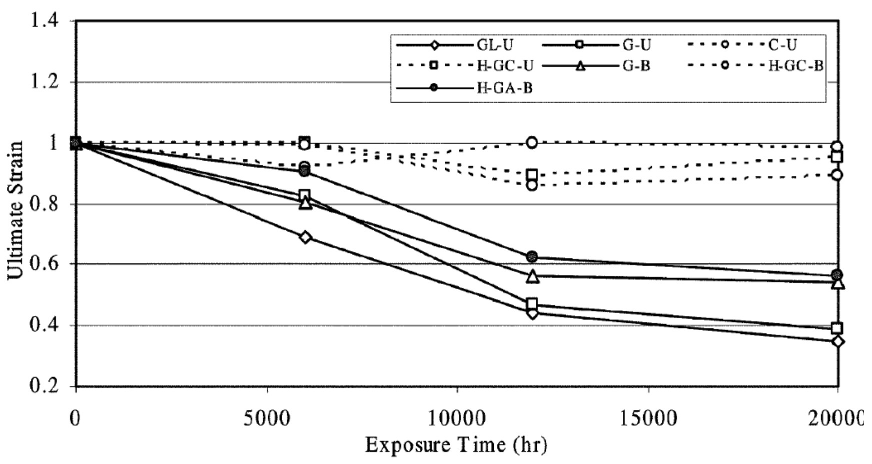
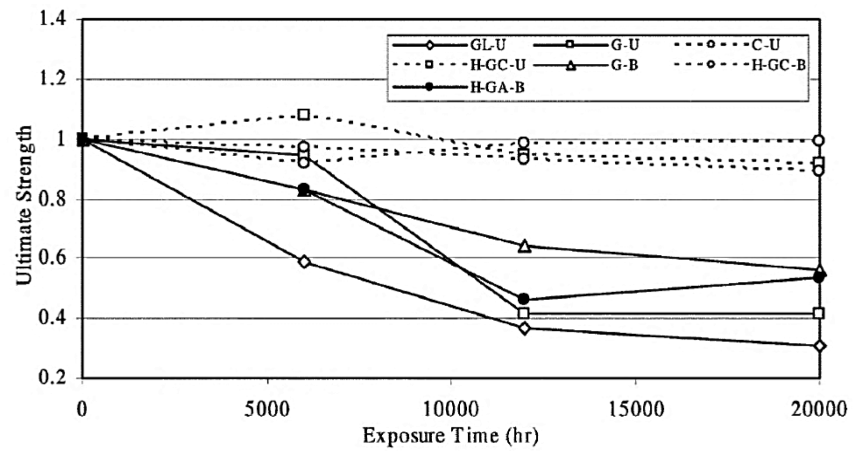
- ❑ Envir. Effects on Mech. Properties of FRP



a) Alkaline Solution (pH = 12.5)



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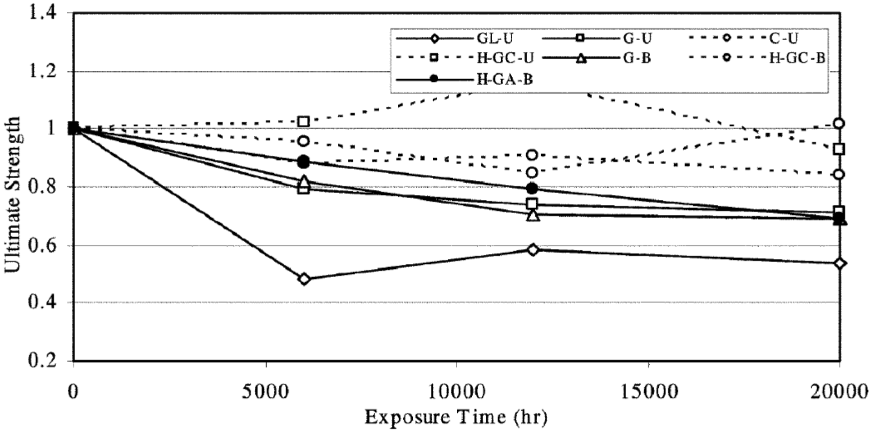
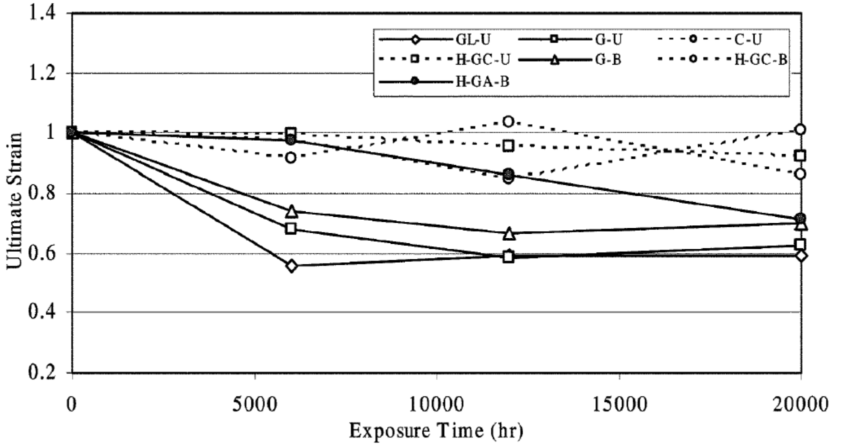


b) Alkaline Solution (pH = 10.0)



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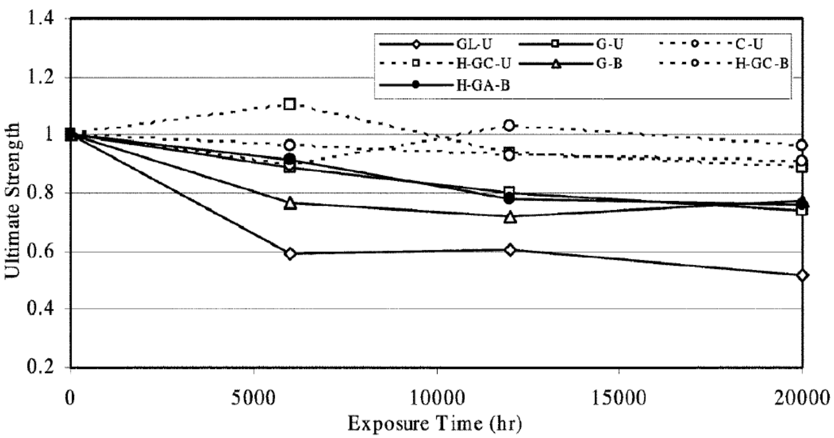
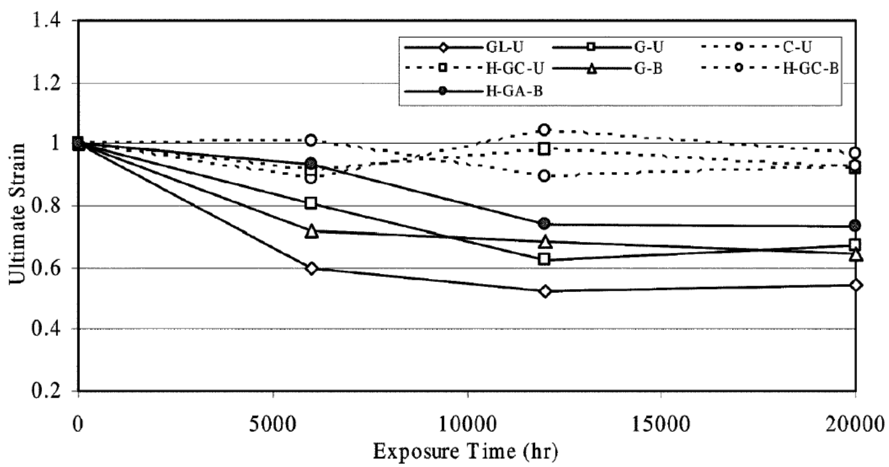
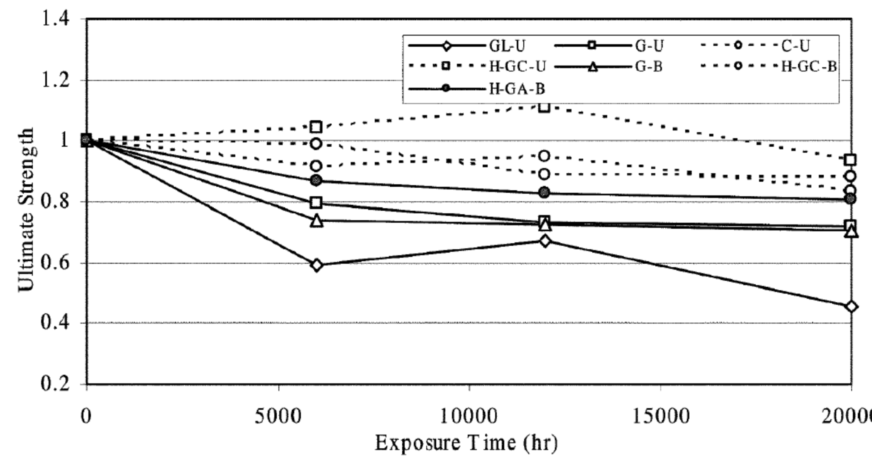


c) Fresh Water Solution (pH = 7.0)

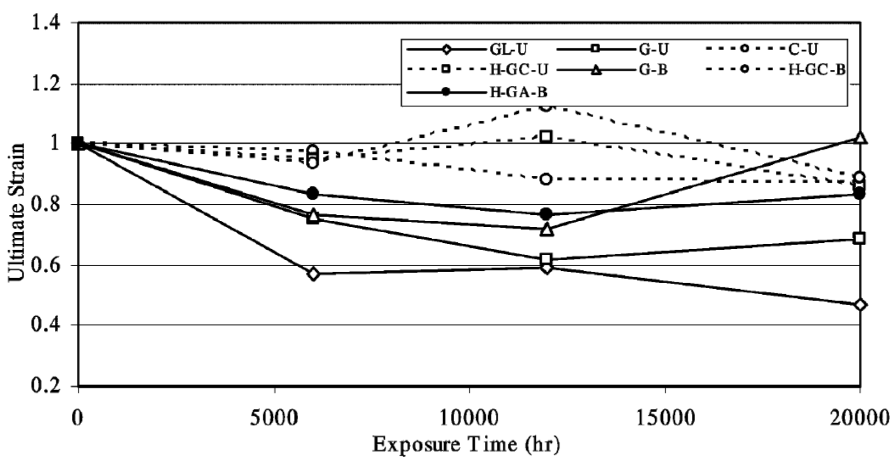


c) Fresh Water Solution (pH = 7.0)

- Envir. Effects on Mech. Properties of FRP



d) Acidic Solution (pH = 2.5)



d) Acidic Solution (pH = 2.5)

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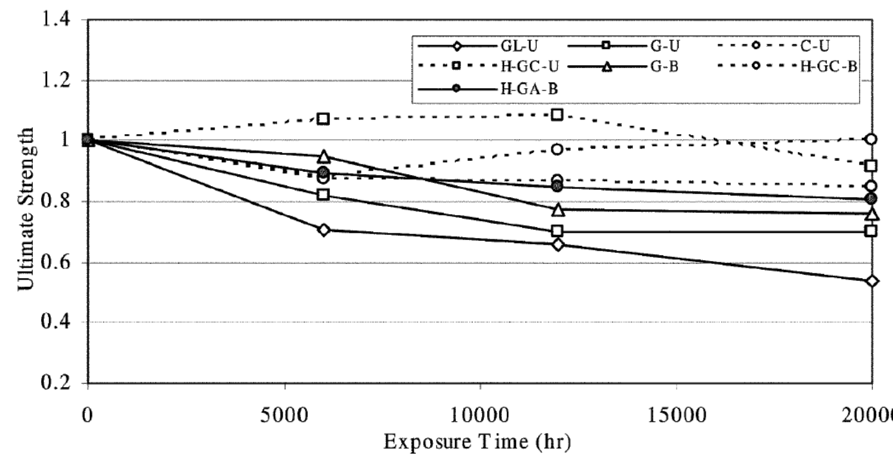
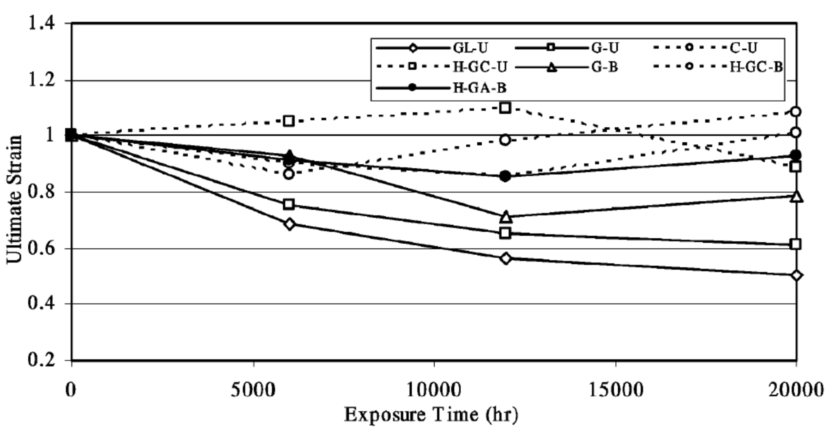
- Envir. Effects on Mech. Properties of FRP



e) Seawater Solution (pH = 7.25)



e) Seawater Solution (pH = 7.25)

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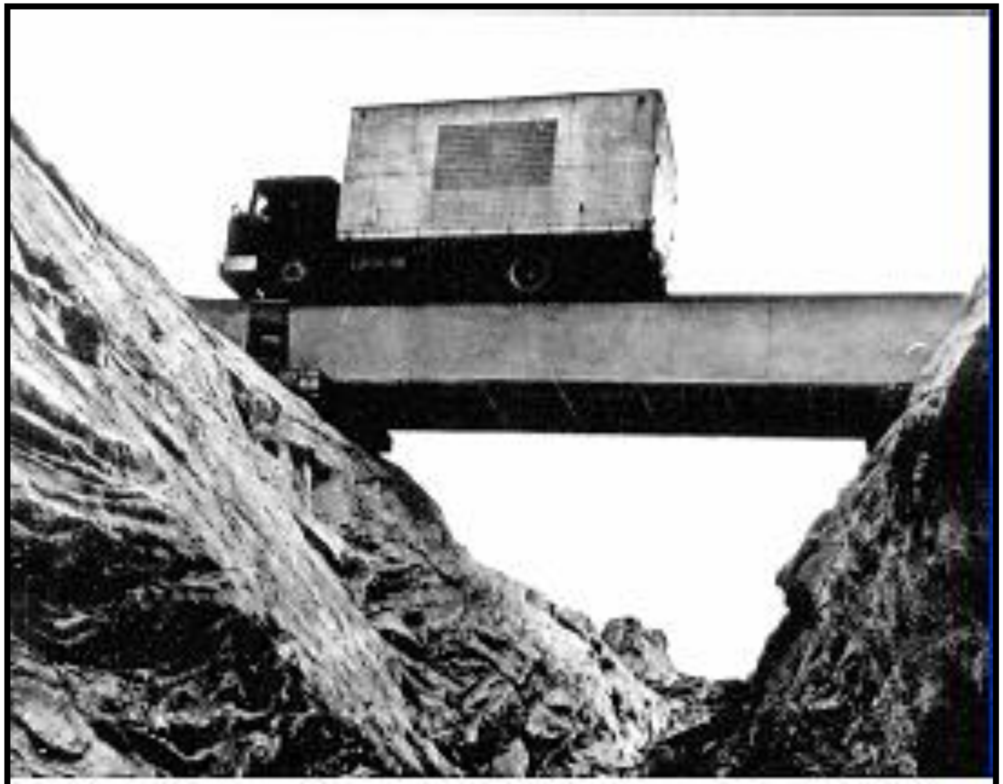
- Application of FRP Composites



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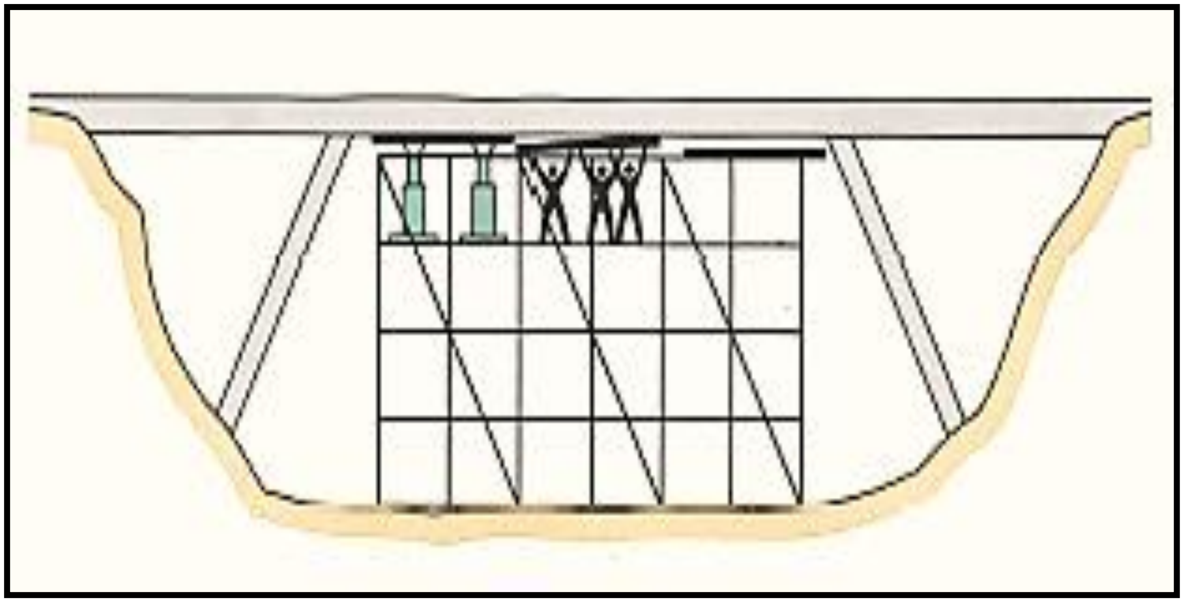
- Post Strengthening using Steel Strips:



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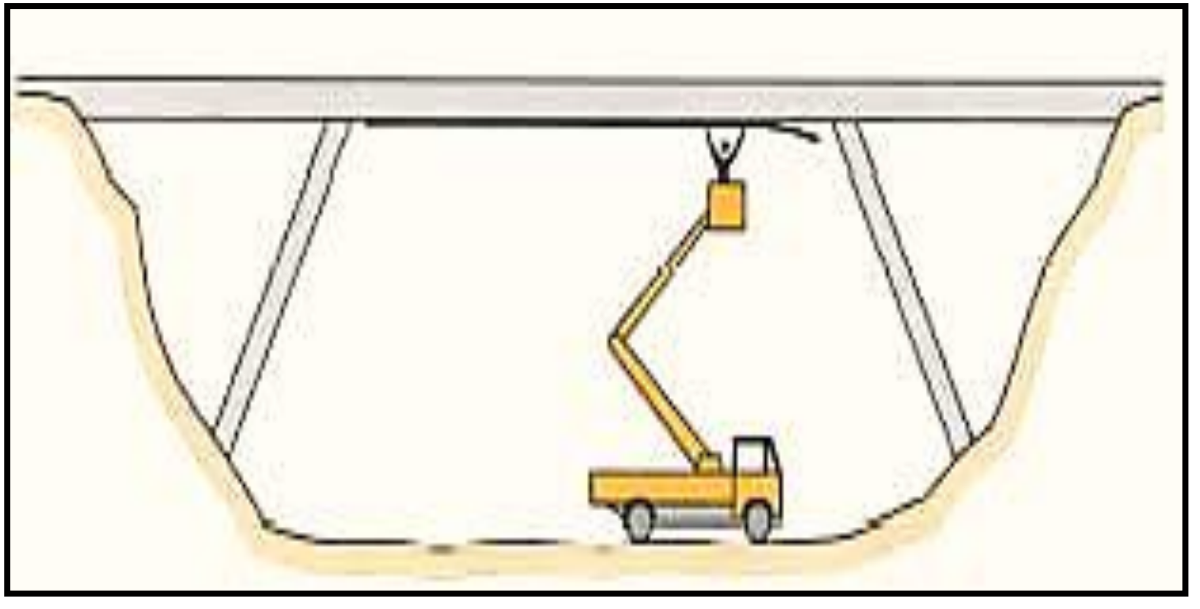
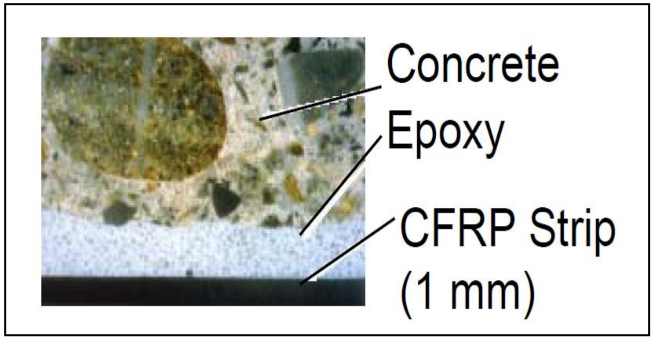
- **Post Strengthening using CFRP Strips:**





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- **Utility Tunnels**

  Tucson Electric Power Pull Box, Tucson, Arizona.

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- **Salt Pond Road Bridge No. 484:**
  (Provience Rhodeisland)

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- **Repair of Steel Pipe Based on the Requirements of ASME PCC/2/2006, Phoenix, Arizona.**

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- **Repair of Pipes with Wet Layup Carbon FRP (CFRP), NM, USA.**

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- **Blast Retrofit:**

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- GFRP Bridge,VA:

- Bridge Decks

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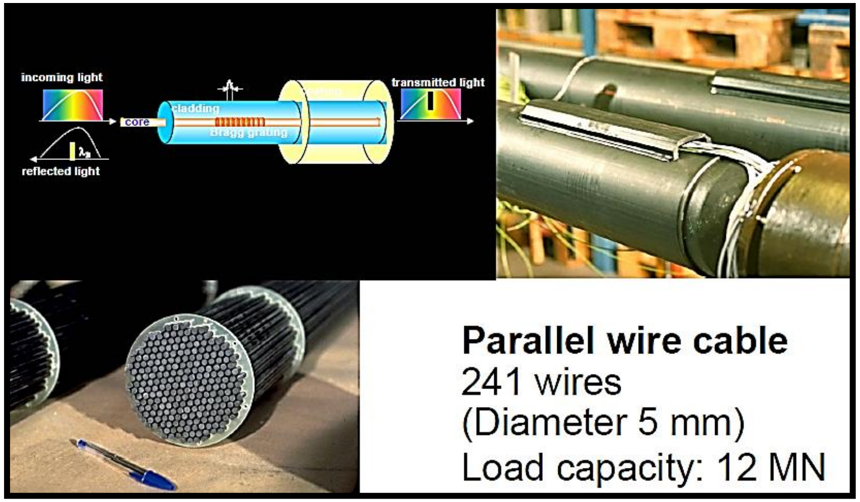
❑ **Storch Bridge 1996, Winterthur, Switzerland:**



- **Span: 124m, 2 Lanes**

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❑ Mechanical Advantage of Composites:

- Specific Modulus

  - Axial Deflection $u = \frac{PL}{EA}$
  - Mass $M = \rho AL$

✓ This implies that the lightest beam for specified deflection under a specified load is one with the highest (E/ρ) value.

Specific Modulus*:*

Specific Modulus:

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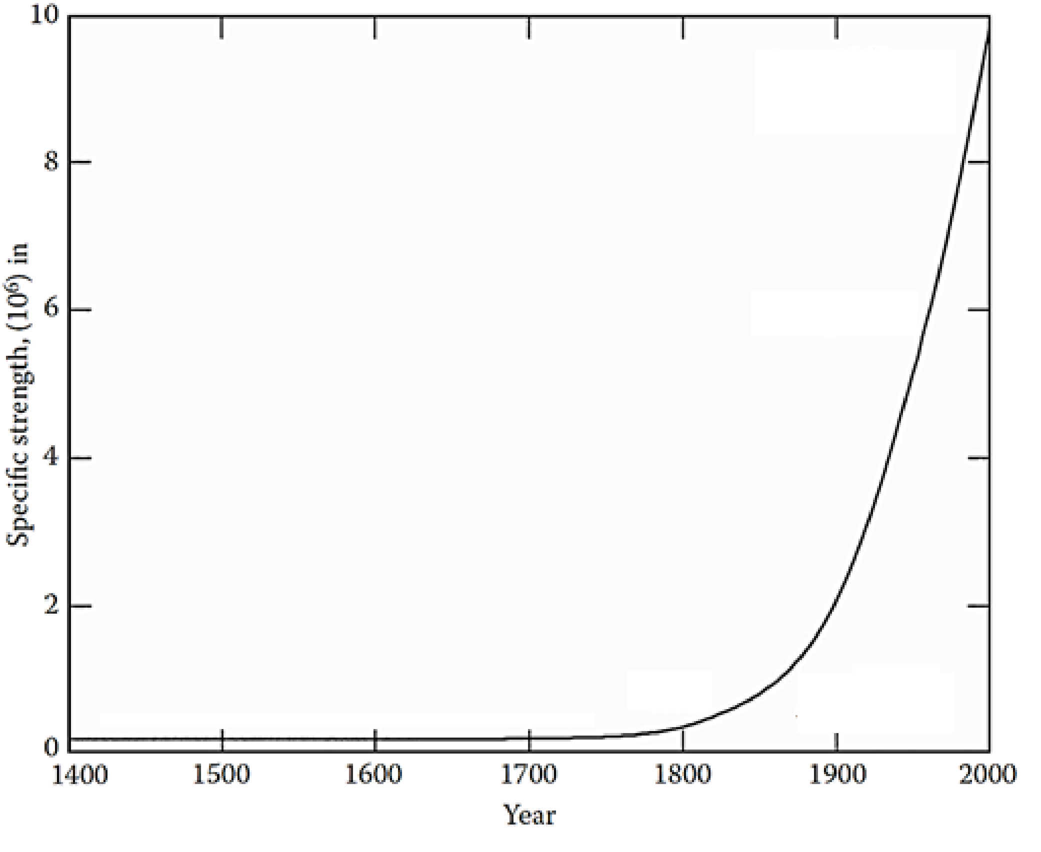
- Specific strength as a function of time of use of materials:



Specific Modulus and Specific Strength of Typical Fibers, Composites, and Bulk Metals.

Material Units	Specific gravity	Young's modulus (GPa)	Ultimate strength (MPa)	Specific modulus (GPa-m³/kg)	Specific strength (MPa-m³/kg)
System of Units: SI					
Graphite fiber	1.8	230.00	2067	0.1278	1.148
Aramid fiber	1.4	124.00	1379	0.08857	0.9850
Glass fiber	2.5	85.00	1550	0.0340	0.6200
Unidirectional graphite/epoxy	1.6	181.00	1500	0.1131	0.9377
Unidirectional glass/epoxy	1.8	38.60	1062	0.02144	0.5900
Cross-ply graphite/epoxy	1.6	95.98	373.0	0.06000	0.2331
Cross-ply glass/epoxy	1.8	23.58	88.25	0.01310	0.0490
Quasi-isotropic graphite/epoxy	1.6	69.64	276.48	0.04353	0.1728
Quasi-isotropic glass/epoxy	1.8	18.96	73.08	0.01053	0.0406
Steel	7.8	206.84	648.1	0.02652	0.08309
Aluminum	2.6	68.95	275.8	0.02652	0.1061

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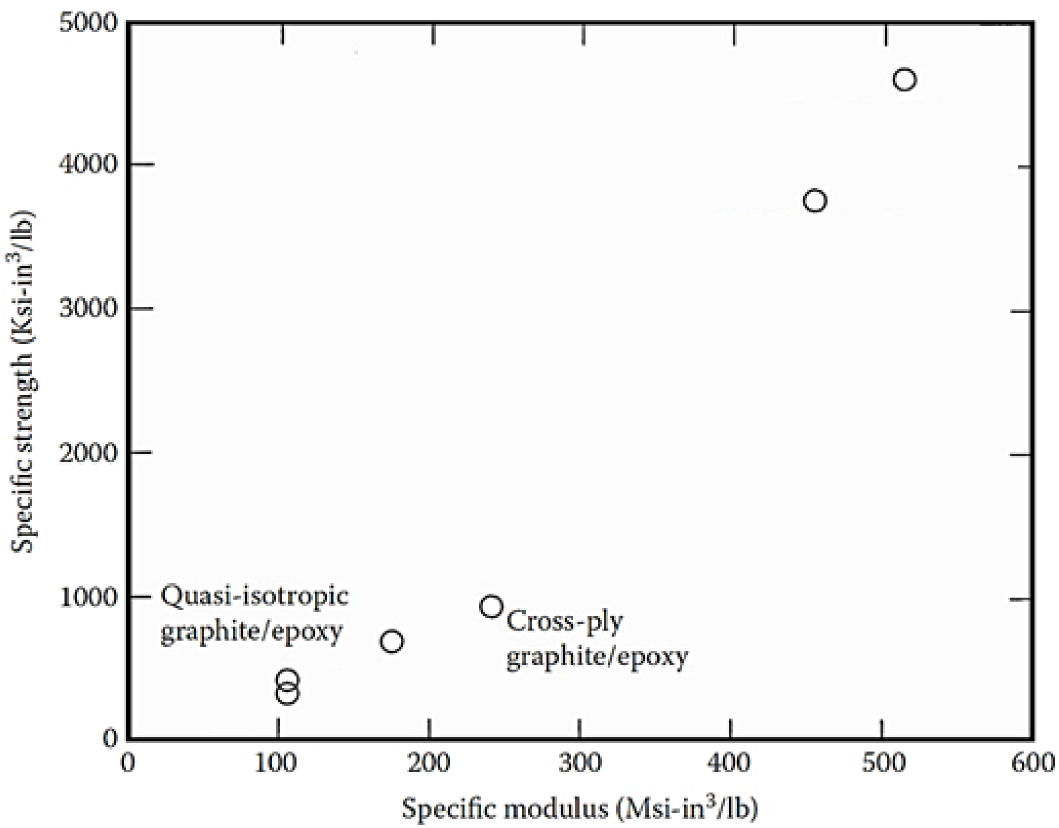
➢ Specific strength as a function of specific modulus for:

-Metals
-Fibers
-Composites



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- Disadvantage of Composite?

- High
- Complex
- Repair of
- Composites do not have a high

- Composites do not necessarily

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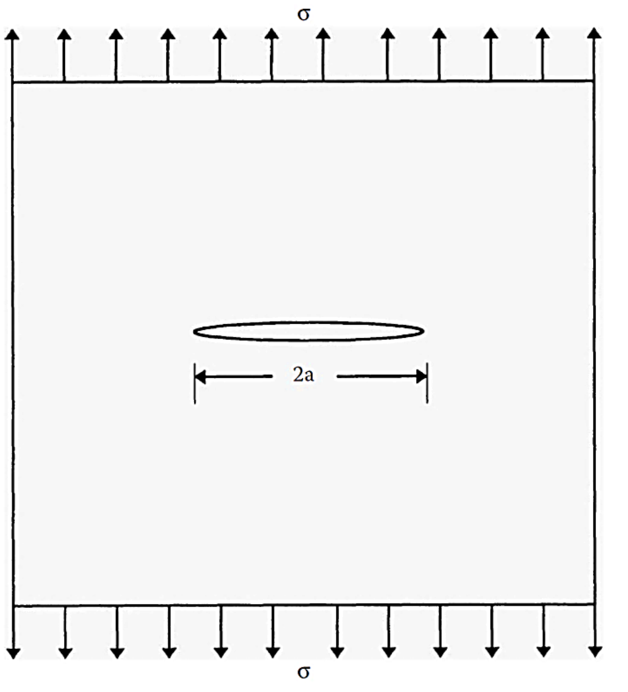
- Fracture Toughness of Composite

For an infinite plate with a crack of length 2*a* under a uniaxial load σ:



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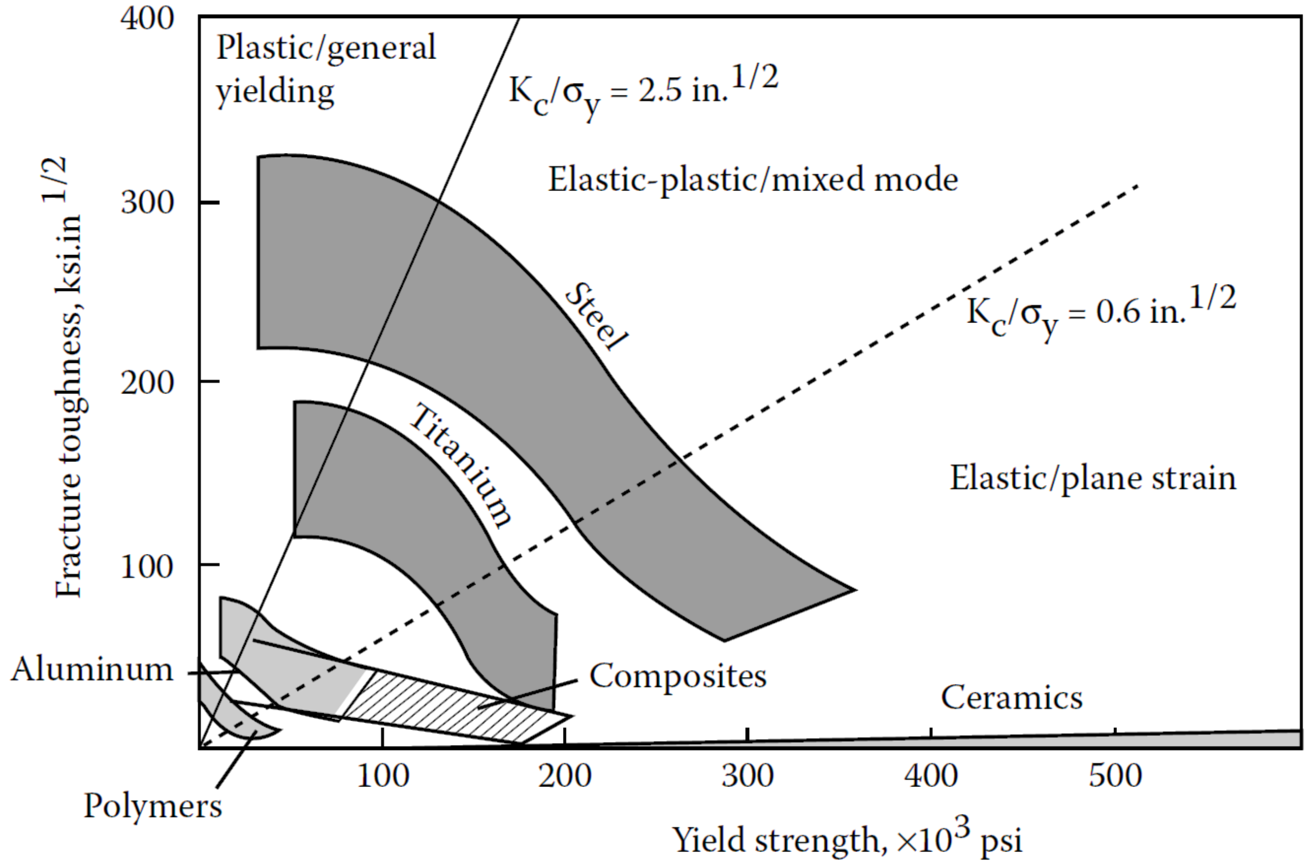
- Fracture toughness as a function of yield strength:



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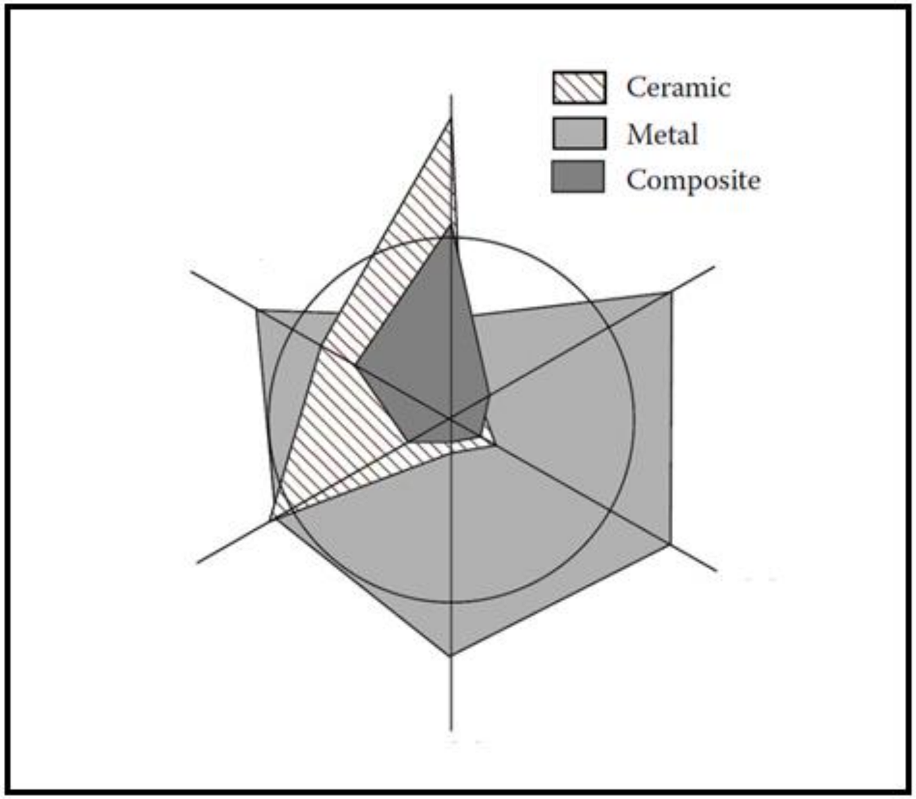
- Primary material selection parameters for a hypothetical situation for:

Metals

Ceramics

Metal-ceramic composites



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❑ Factors vs. Mechanical Performance:

a) Fiber Factors

-L	-O
-S	-M

b) Matrix Factors

c) Fiber-Matrix Interface

-C	-N
-T	-R

Type of Composites:

- Particulate composites
- Flake composites
- Fiber composites

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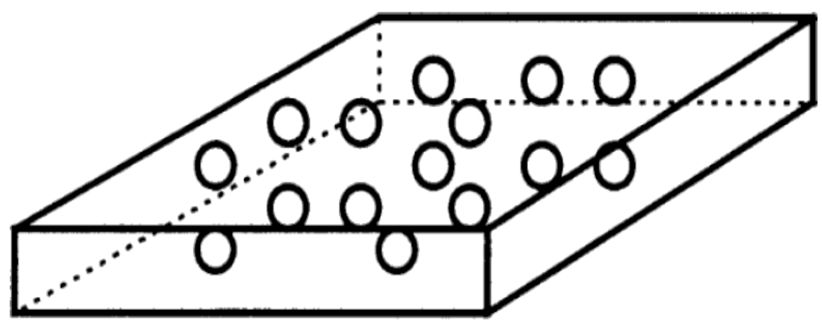
❑ Particulate Composites



Particulate composites

Advantage: improved strength, increased operating temperature and oxidation resistance

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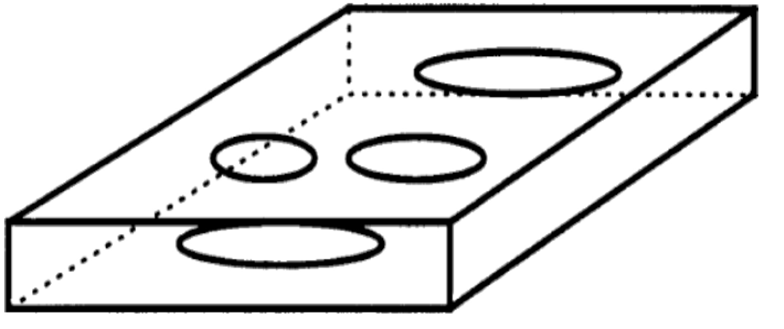
❑ Flake Composites


Flake composites

Advantage: high out-of-plane flexural modulus,
higher strength, and low cost.

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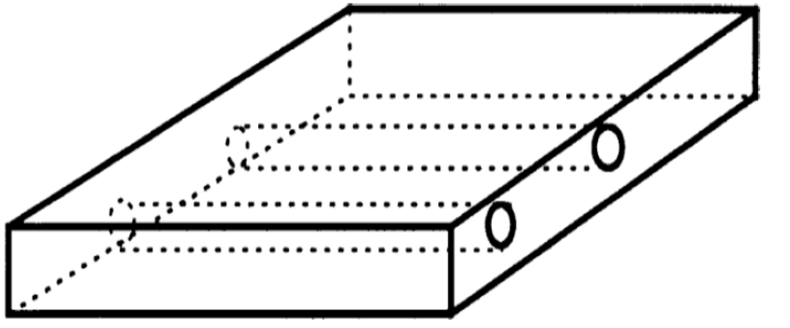
- ## Fiber Composites


Fiber composites