Class 1: Introduction to Composites in Civil Infrastructure

Ulenbergstrasse Suspension Bridge with FRP tension cables (Düsseldorf, Germany)

FRP wrap on a column (UF Law School)

Full bridge Structures (Parson's Bridge, Whales)

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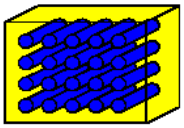
Top Middle: Brown, Jeff. Infrared Thermography Inspection of Fiber Reinforced Polymer Composites Bonded to Concrete
Top Right: Strongwell Corporation, 2003

PRIME Modules
Project-based Resources for Introduction to Materials Engineering

A composite is a multiphase material that is engineered to gain benefits from both layers

There are many natural composites such as wood and pearlite (steel which is a mixture of a phase and Fe_3C).

From a materials engineering standpoint, "composite" is typically used to refer to two (or more) phase systems that are purposely engineered to maximize the benefits of both layers



Fiber Reinforced Composite

"A multiphase material which is artificially made of chemically dissimilar materials separated by a distinct interface."
William D. Callister, Jr - "Materials Science and Engineering an Introduction"

http://www.mse.cornell.edu/courses/engri111/compo.htm

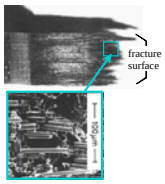
A composite is made up of a matrix, fiber or particle, and interface

The matrix phase is the continuous phase that provides durability to the composite. (ie: concrete in reinforced concrete)

The dispersed phase (such as a fiber or particle) provides strength to the composite. (ie: steel rods in reinforced concrete)

The interface region is where the two phases meet.

Glass w/SiC fibers.



From Callister. Adapted From F.L. Matthews and R.L. Rawlings, *Composite Materials; Engineering and Science*, Reprint ed., CRC Press, Boca Raton, FL, 2000. (a) Fig. 4.22, p. 145 (photo by J. Davies); (b) Fig. 11.20, p. 349 (micrograph by H.S. Kim, P.S. Rodgers, and R.D. Rawlings). Used with permission of CRC Press, Boca Raton, FL.

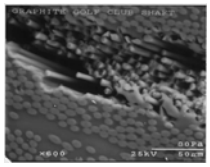
Some possible matrix materials include polymers, metals, and ceramics

Thermoset polymers (epoxies, esters and imides) are used with continuous fiber composites

Thermoplastic polymers are used with discontinuous fiber composites

Metal matrices are good for high temperature applications

Ceramic matrices are good for High temperature/corrosive environment use



Metal Matrix in graphite reinforced golf club shaft

http://www.engr.sjsu.edu/WofMatE/Composites.htm

Some possible fiber materials include glass, graphite, polymers, and ceramics.

Glass: Low cost, most common fiber material

Carbon (Graphite): High strength, stiffness and cost.

Aramid (Kevlar): High strength to weight ratio, difficult to process

Polyethylene (Spectra): High strength to weight ratio, difficult to process, poor matrix adhesion

Boron: High compressive strength and very high cost

Silicon Carbide and Alumina: High temperature use and high cost

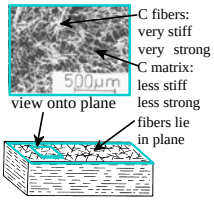
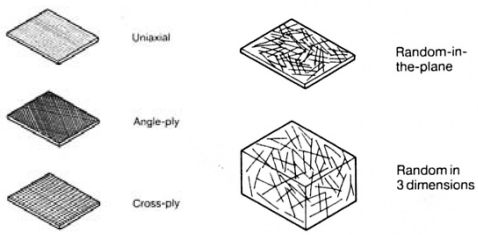


Figure adapted from Callister which was adapted from F.L. Matthews and R.L. Rawlings, *Composite Materials; Engineering and Science*, Reprint ed., CRC Press, Boca Raton, FL, 2000. (a) Fig. 4.24(a), p. 151; (b) Fig. 4.24(b) p. 151. (Courtesy I.J. Davies) Reproduced with permission of CRC Press, Boca Raton, FL.

The fibers can be arranged in the matrix in a range of different modes

The arrangement of the fiber in the matrix critically influences the composite properties



Composites are widely used in civil engineering infrastructure

Concrete is a ceramic composite itself of mortar and stone

Reinforced concrete is a cross-ply composite with a concrete matrix and steel fibers

FRP - Fiber Reinforced Polymer is a composite with a polymer matrix and glass, carbon or aramid fiber that is used primarily to patch concrete in civil infrastructures

Concrete aggregate of mortar and stone

http://en.wikipedia.org/wiki/Aggregate_(composite)

Advantages of FRP include low cost, high strength , and corrosion resistant

FRP has a low cost considering
- **Relative cost of the composite**
- **Cost of installation versus replacement**
- **Cost of installation time (both direct and indirect)**

High strength to weight ratio

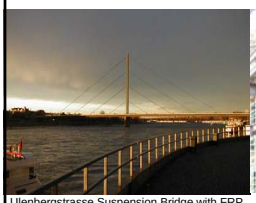
Corrosion resistant

Can be tailored for the application (both shape and type of FRP)

Hall's Harbor - World's first fully composite reinforcement Warf

http://www.new-technologies.org/ECT/Civil/frprebar.htm

Where are FRPs Used?



Ulenbergstrasse Suspension Bridge with FRP tension cables (Düsseldorf, Germany)

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FRP Bridge Structural Beam Repair

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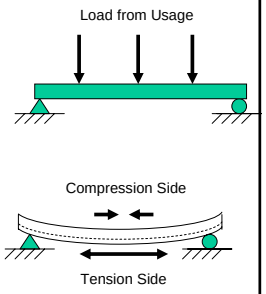
Left: Wipf, Terry. "Installation of carbon fiber reinforced polymers (CFRP) post-tensioning bars."

A bridge flexes under normal use creating a compressive and tensile side

A bridge member is designed to flex under applied load with a given factor of safety based on materials and mechanical design.

This flexing puts the top side in compression and the bottom side in tension.

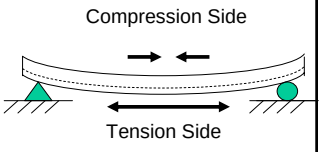


Failure of the bridge can occur on the tensile side

The bridge member may degrade over time due to aging of the concrete or corrosion of the steel bars.

If it is then subjected to an oversized load for the current state of the member the reinforcing steel rods can break in tension.

The tensile reinforcement is then reduced.



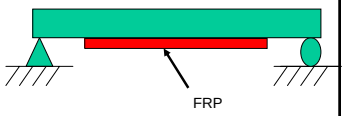
In previous cases, the bridge was then repaired by replacing the failed beams

The previous practice was to replace the failed beams.

This had several drawbacks including
- **Expensive materials needed for repair**
- **Skilled labor needed (expensive as well)**
- **Heavy machinery is used (expensive to move and maintain)**
- **Time consuming:**
  - **Closure of traffic disrupts normal flow**
  - **Workers are devoted to repair instead of new projects**

A new practice is to patch the failed member with an FRP

A new practice is to patch the failed member with an FRP on the tensile side.



In this module we are going to study:

- What are the properties of the FRP?
- How can the FRP stand the environment?

FRP Bridge Structural Beam Repair

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In summary, composites are multiphase materials engineered to maximize the benefits of both components

Composites are made up of a matrix, fiber, and interface. The layers are engineered to maximize the benefits of each component.

Concrete and steel-reinforced concrete are common composites used in civil infrastructure

Fiber reinforced polymers are relatively new composites whose primary usage is to patch concrete

FRP Bridge Structural Beam Repair

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