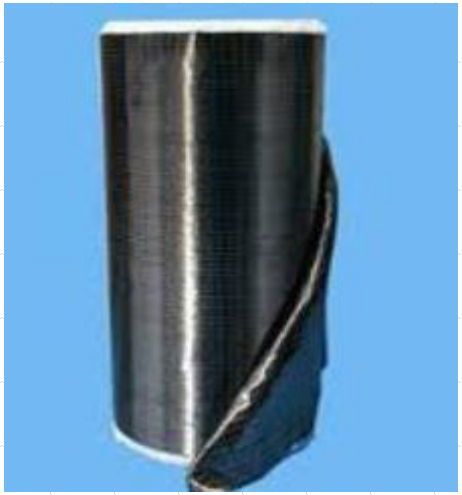
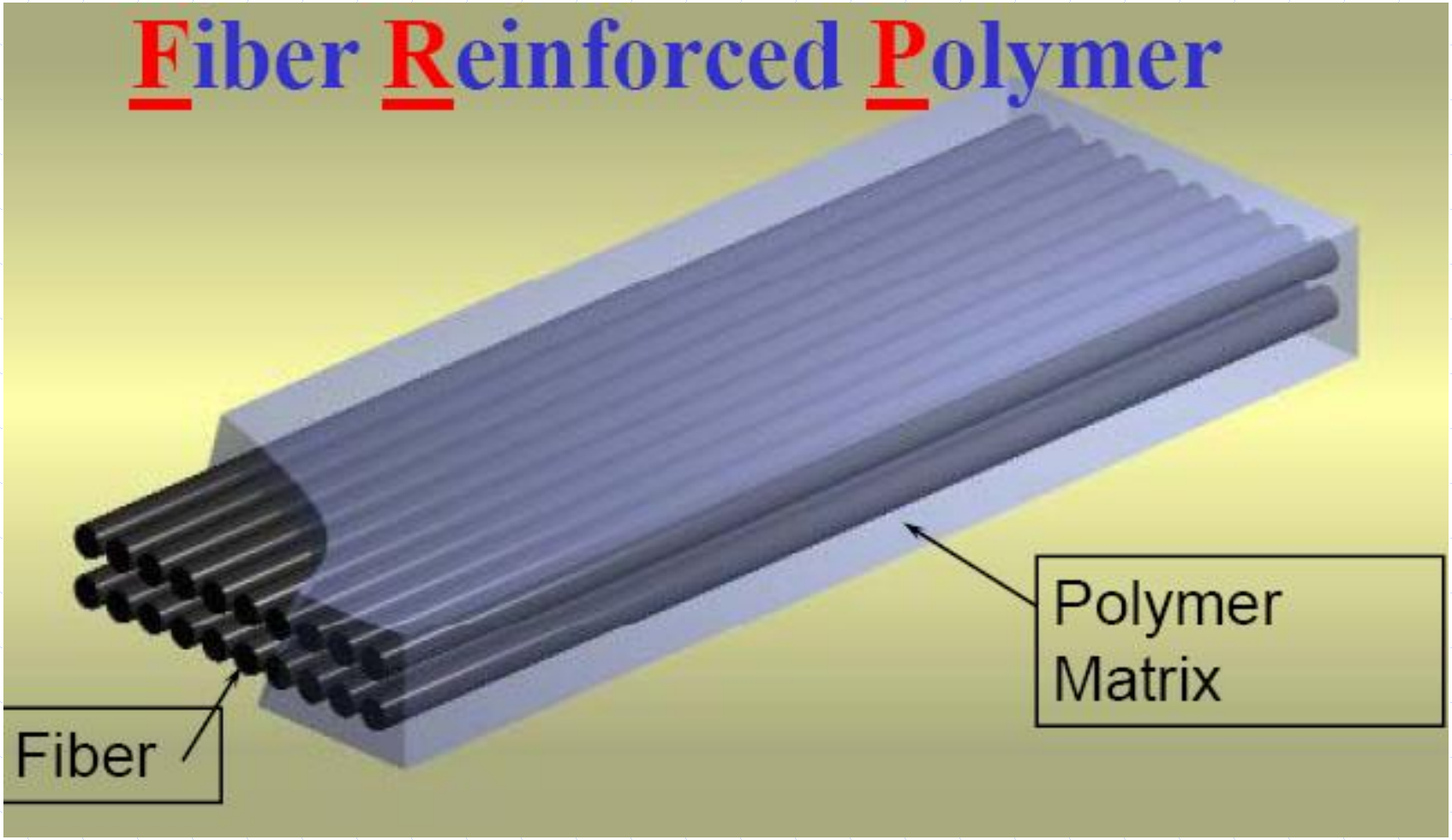


Fiber Reinforced Polymer (FRP)

Dr. Safeer Abbas

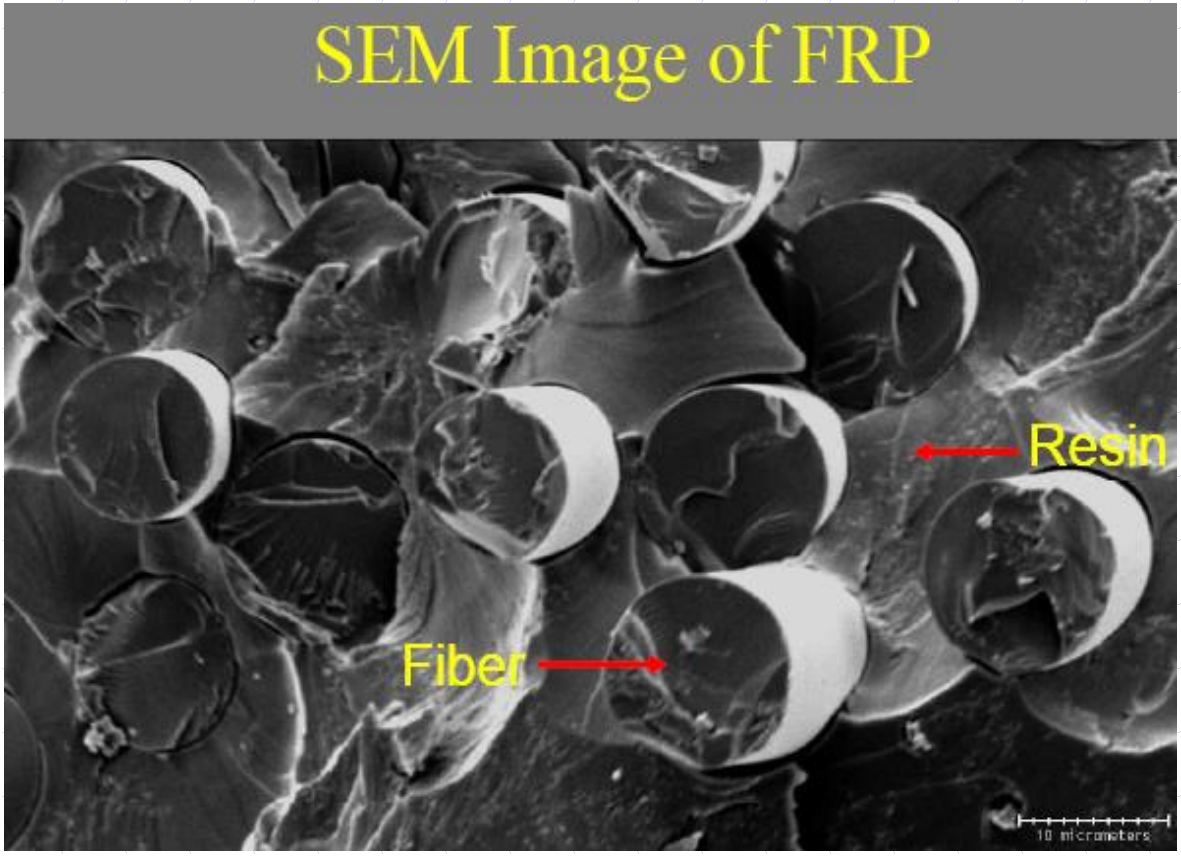
Fiber Reinforced Polymer (FRP)



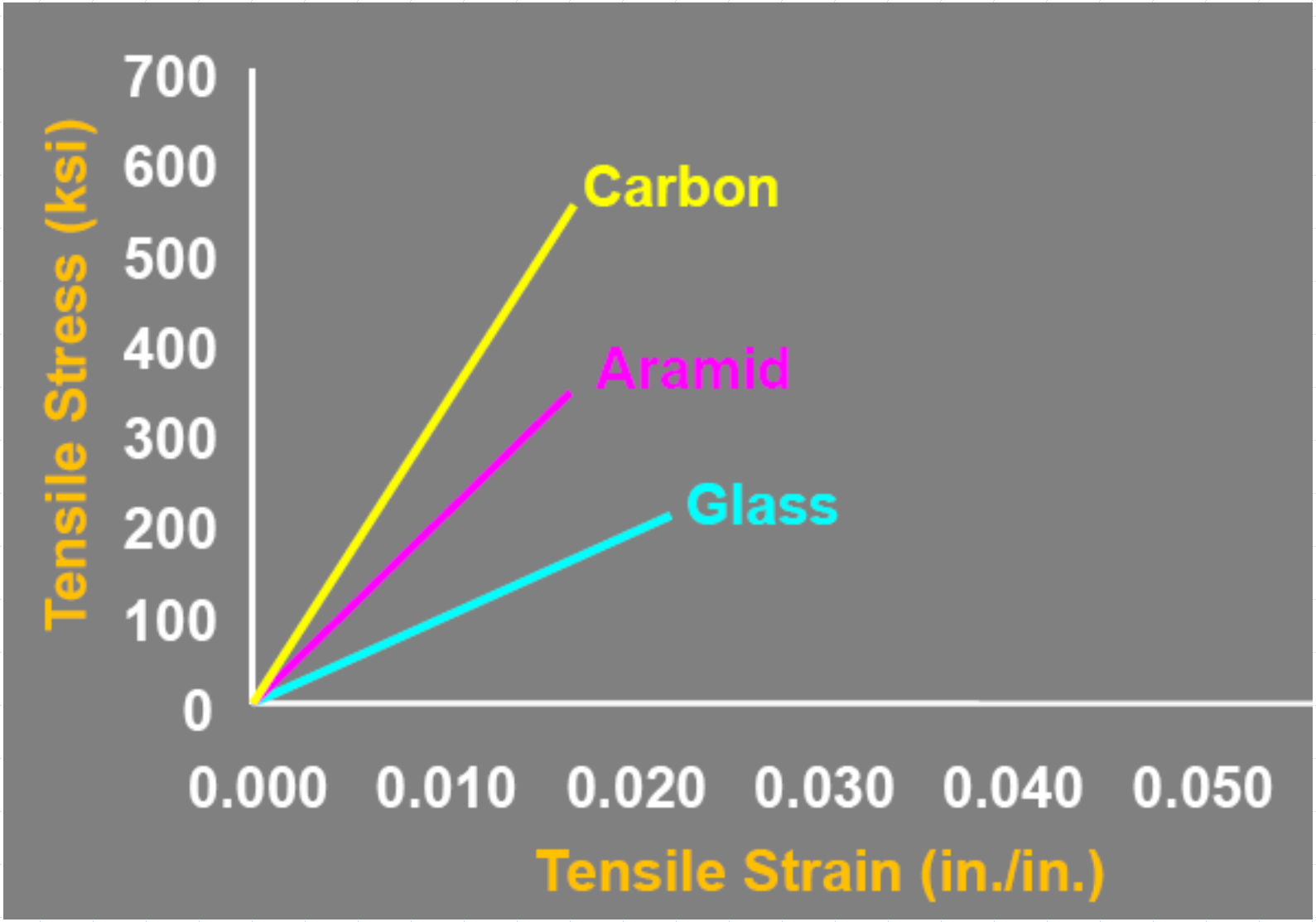
FRP Constituent Materials

- **Fibers**
  - Carbon
  - Glass
  - Aramid
  - Others

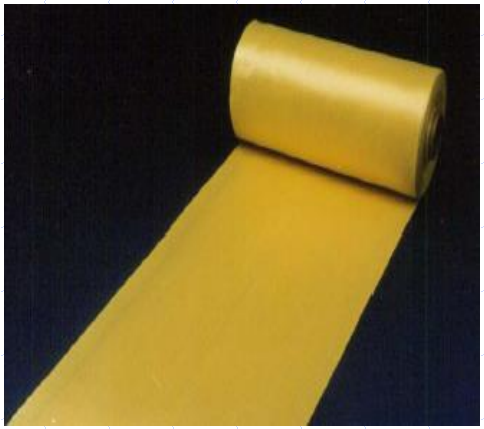
- **Resins**
  - Epoxy
  - Vinyl Ester
  - Phenolic
  - Others

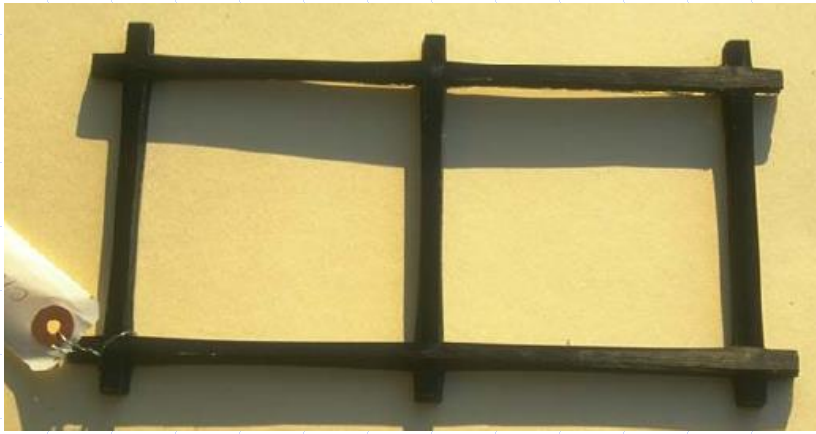


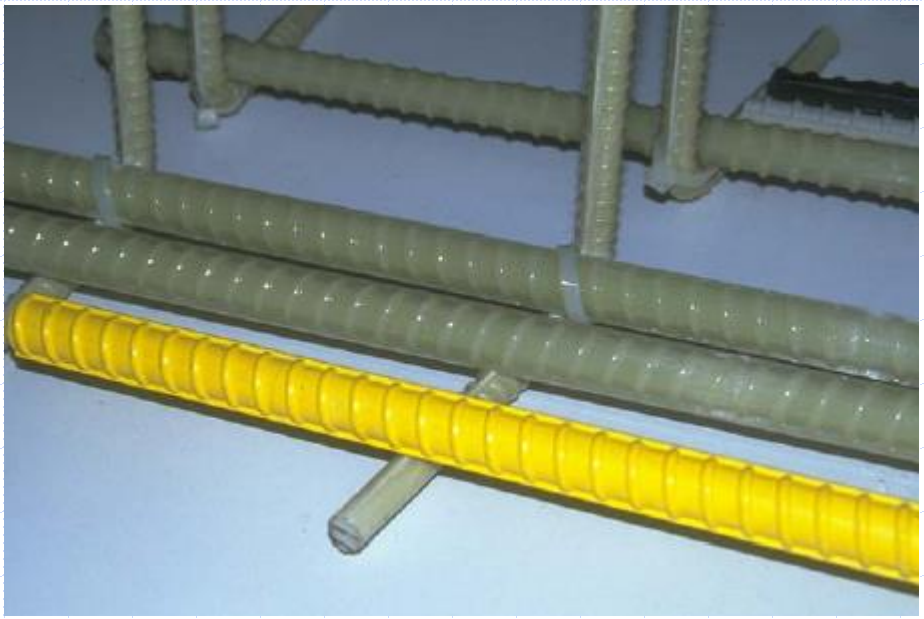
Fiber Material Behavior



Commercial FRP Systems

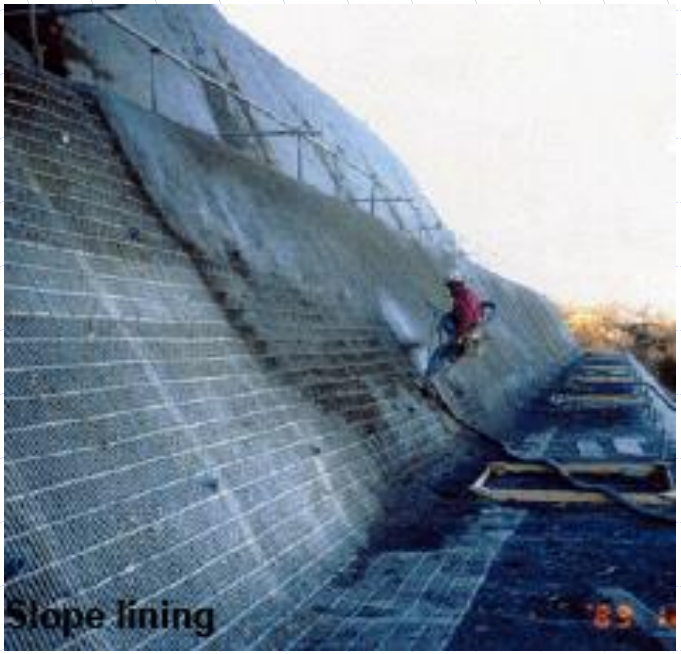


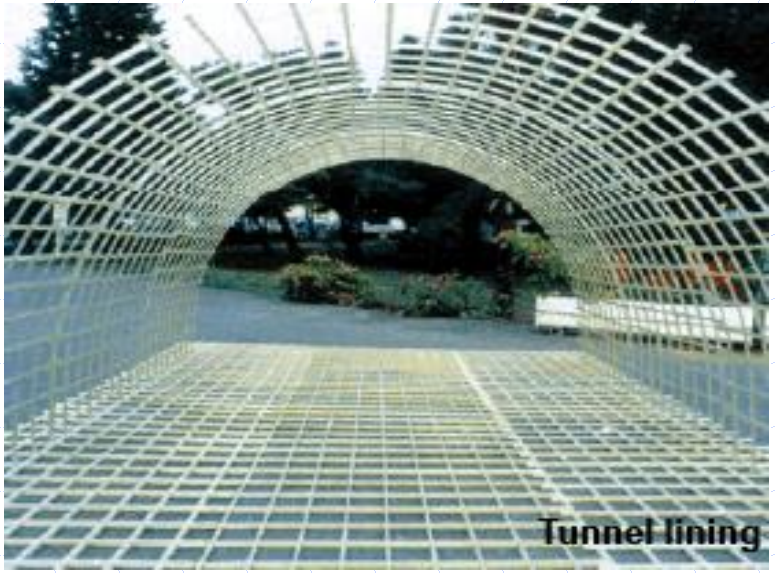




FRP Strengthening

Application of FRP in new Construction

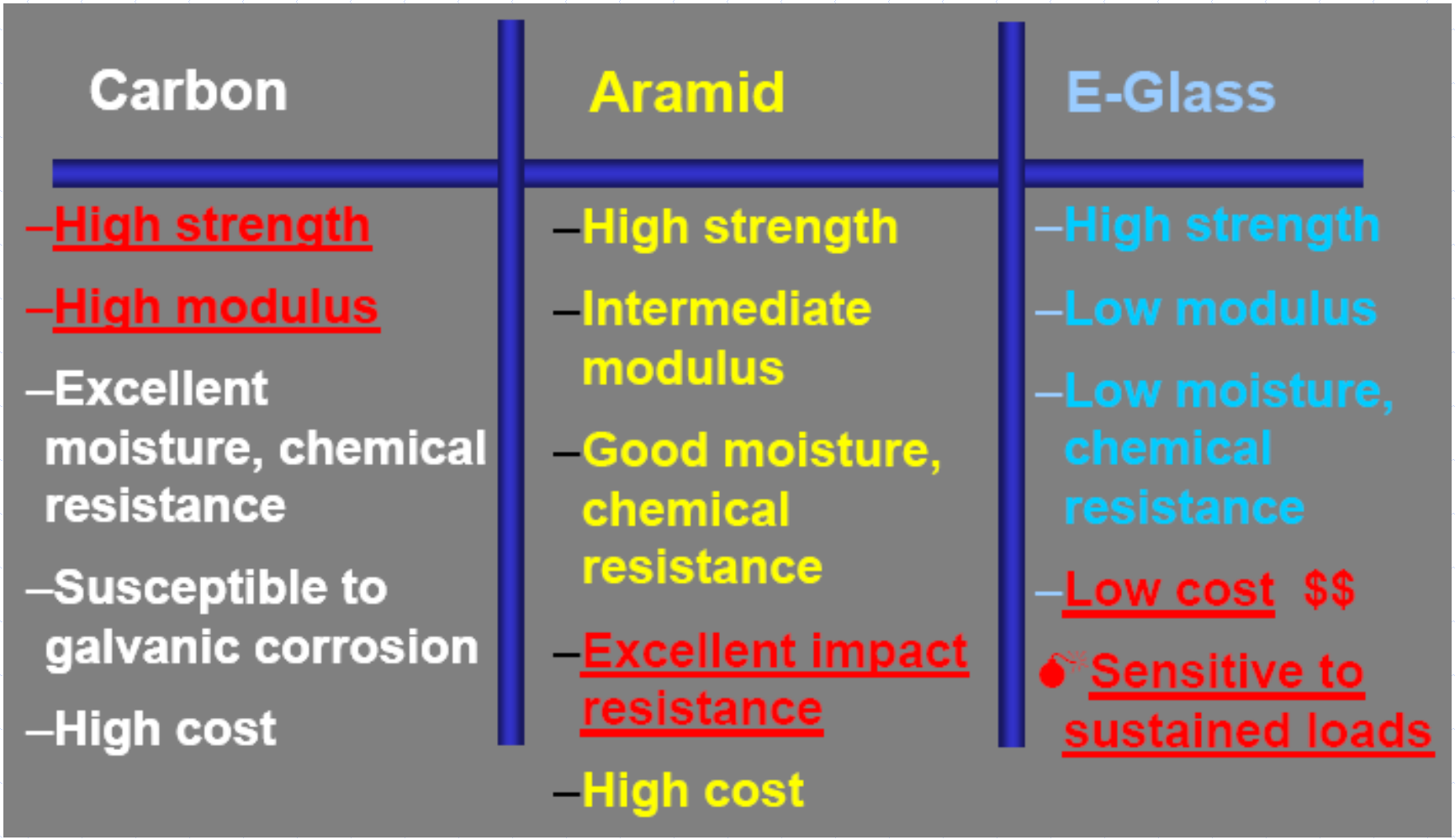




Why use FRP

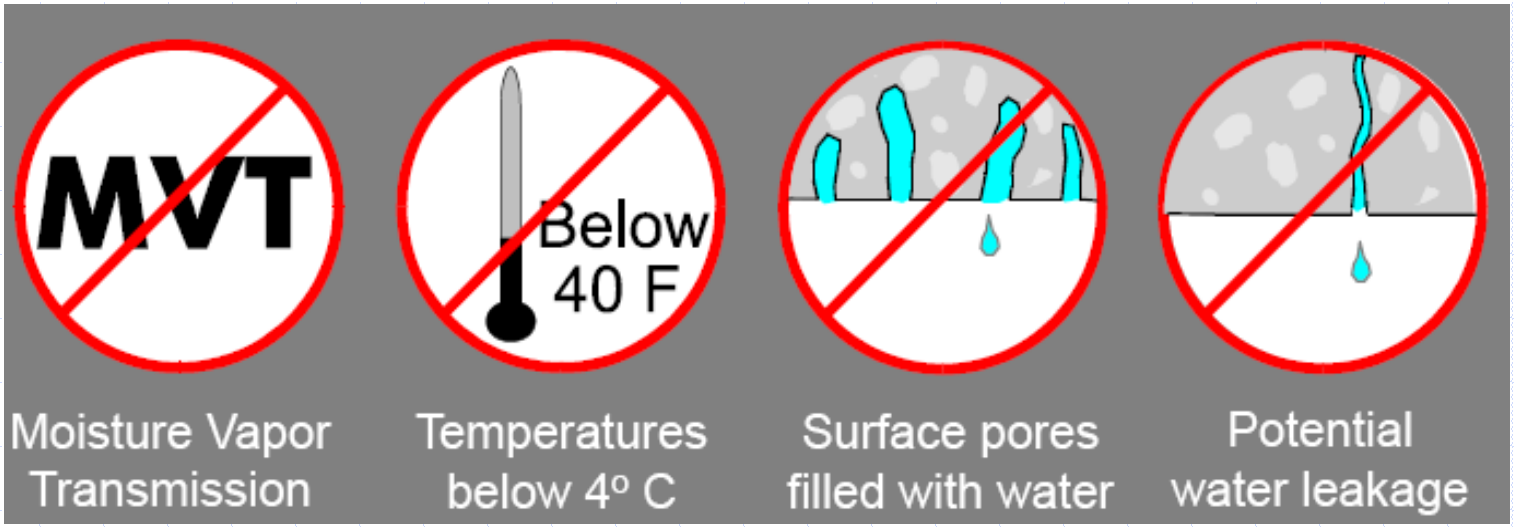
- Structural Benefits
  - Very high strength and stiffness
  - Lightweight
- Life Cycle Benefits
  - Corrosion resistant
  - Thin, unnoticeable
- Economic Benefits
  - Low installation costs
  - Quick Turnaround

Fiber Material Comparison



Installation of FRP systems

- Proper usage
- Installation and service environment
- Preparation of substrate
- Proper installation technique
- QA/QC

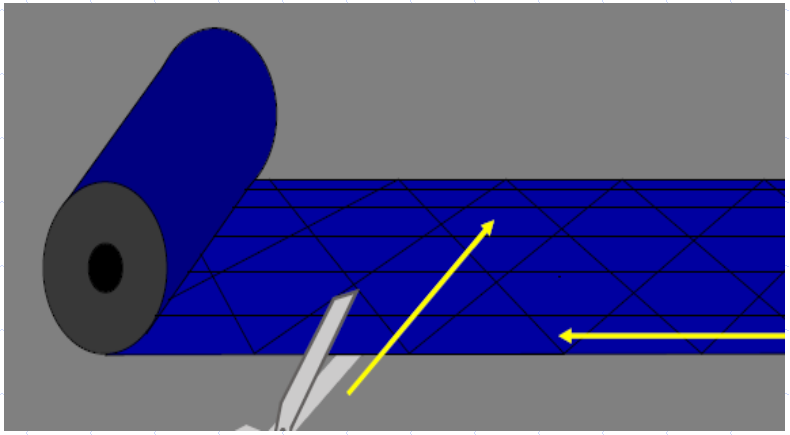


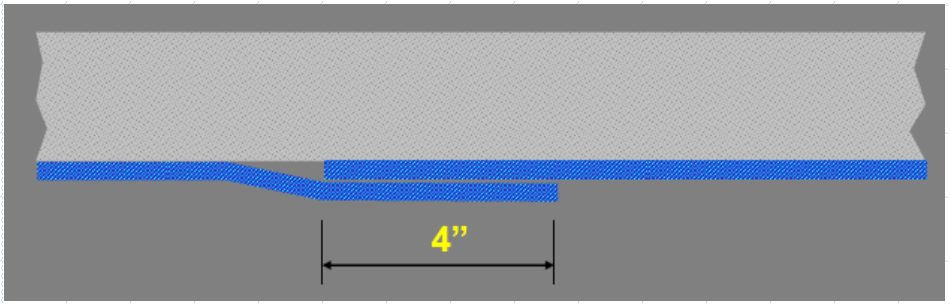
Installation of FRP systems

- Need adequate repair of substrate
- Eliminate form line by grinding/applying putty
- Applying putty to formlines and bugholes

Installation of FRP systems

- Apply first saturant layer
- Cutting of FRP sheets
- Install sheets





Installation of FRP systems

- Apply 2nd saturant layer
- Apply topcoat

FRP Strip Installation

- Set strip by hand
- Apply gel
- Work from one end
- Apply pressure

FRP Strengthening Application

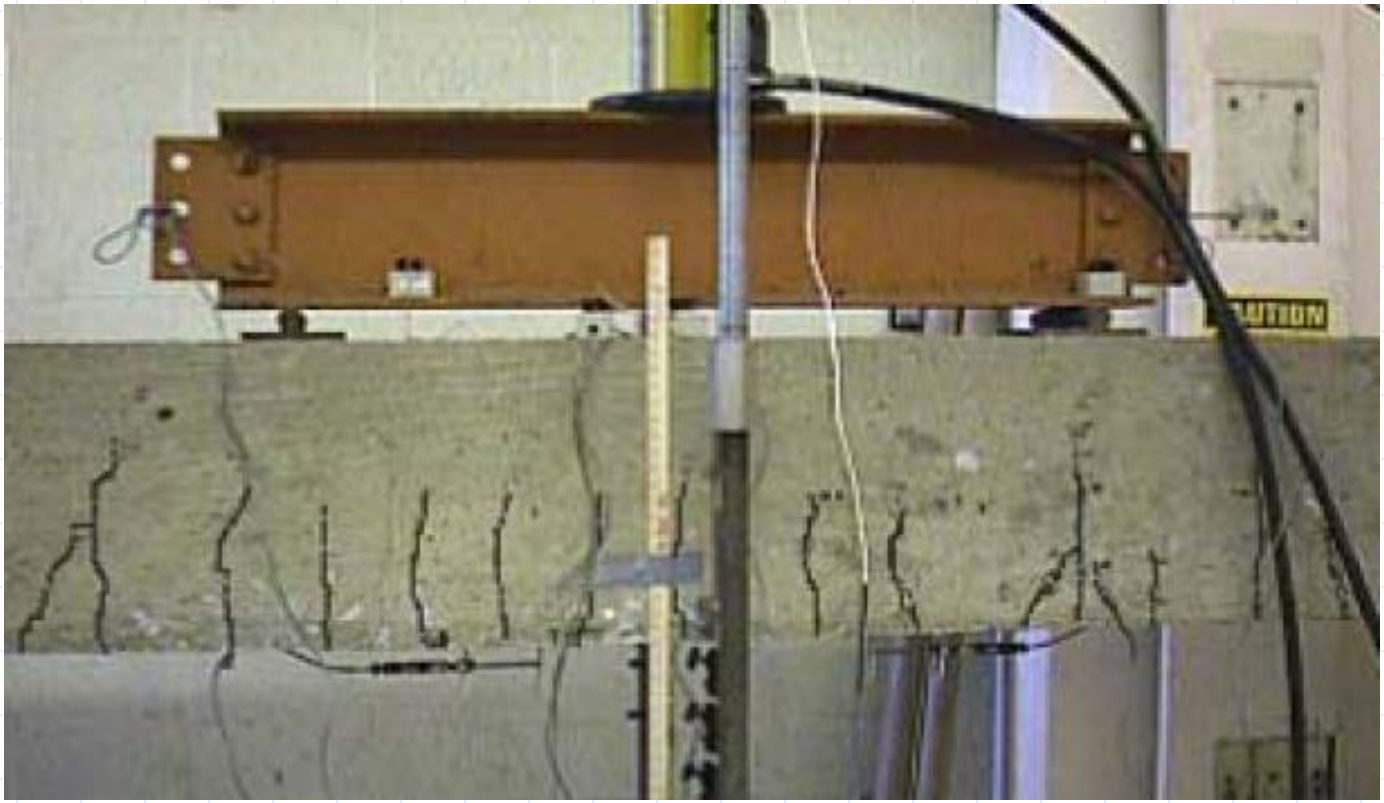
- Change in Use…New Loads
- Construction or Design Defects…Oops!
- Code Changes…New Design Criteria
- Seismic Retrofit…Event Risk Management
- Core Drills and Big Trucks...

FRP Strengthening Application

Flexural Strengthening

Usually needed when:

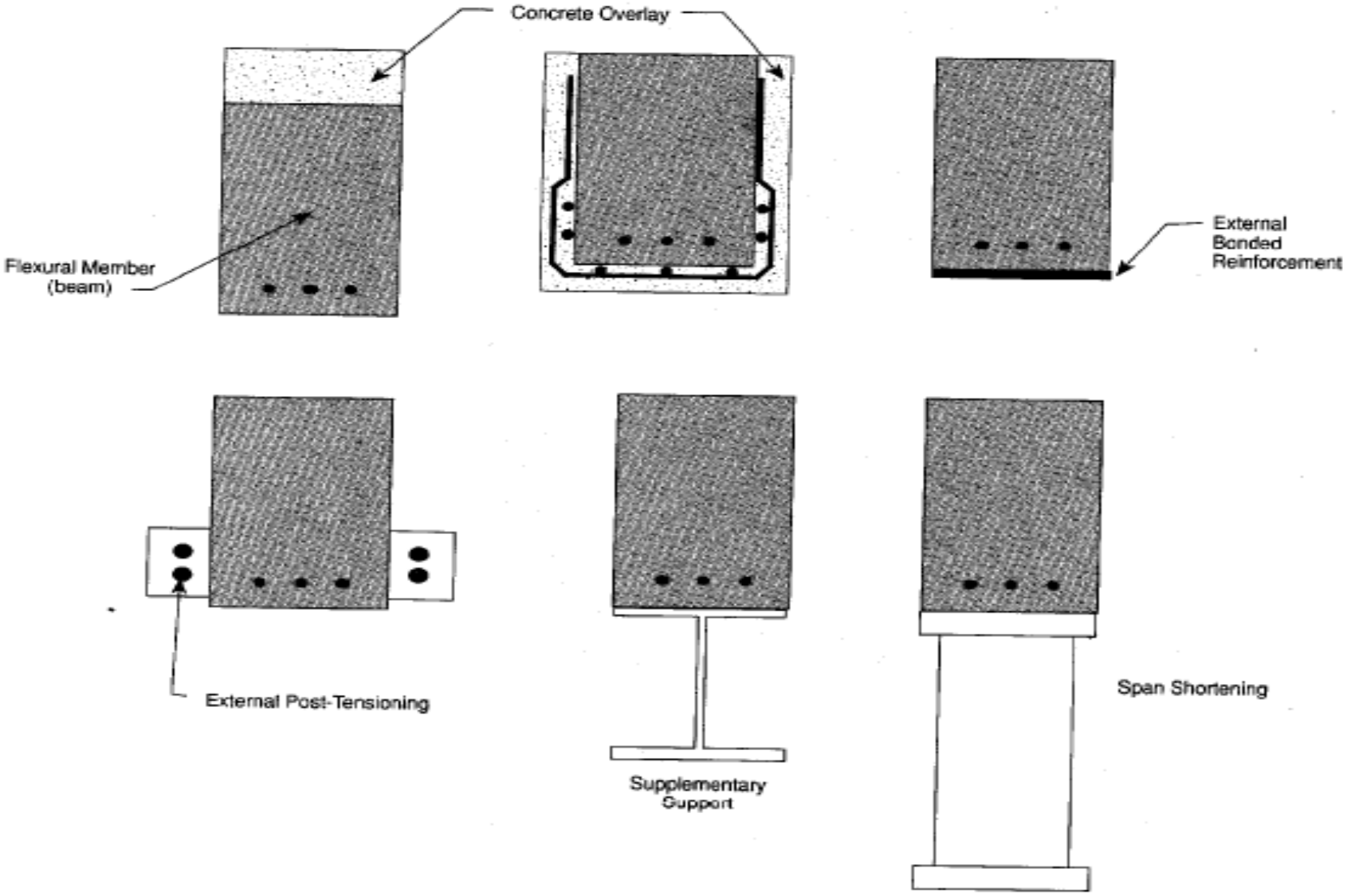
- Design deficiency uncovered
- Excessive deflection occurs
- Additional loads are anticipated



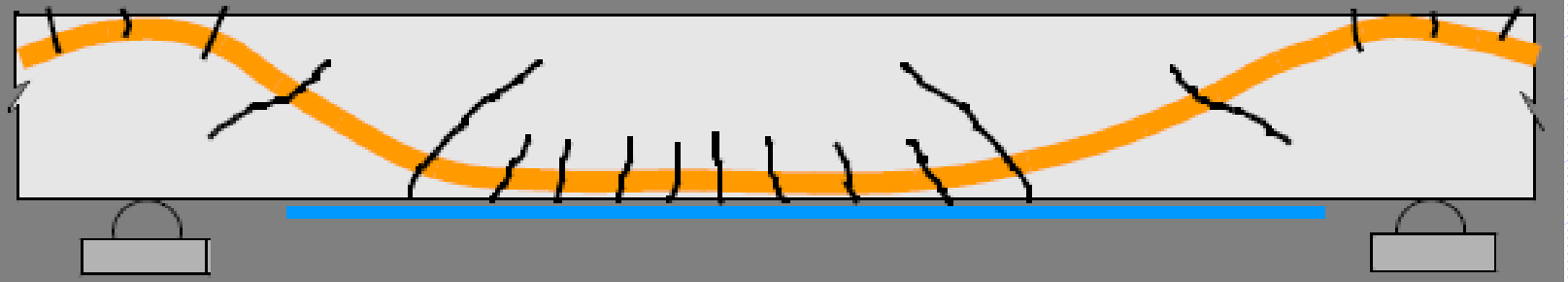
Flexural Design

- Ultimate Strength Design / Serviceability Checks
- ACI 318 Load Factors & ϕ Factors
- Increase ϕM_n (M_n: nominal moment capacity, ϕ: strength reduction factor)
- Maintain Ductility
- Simple Design Procedure

Flexural Design



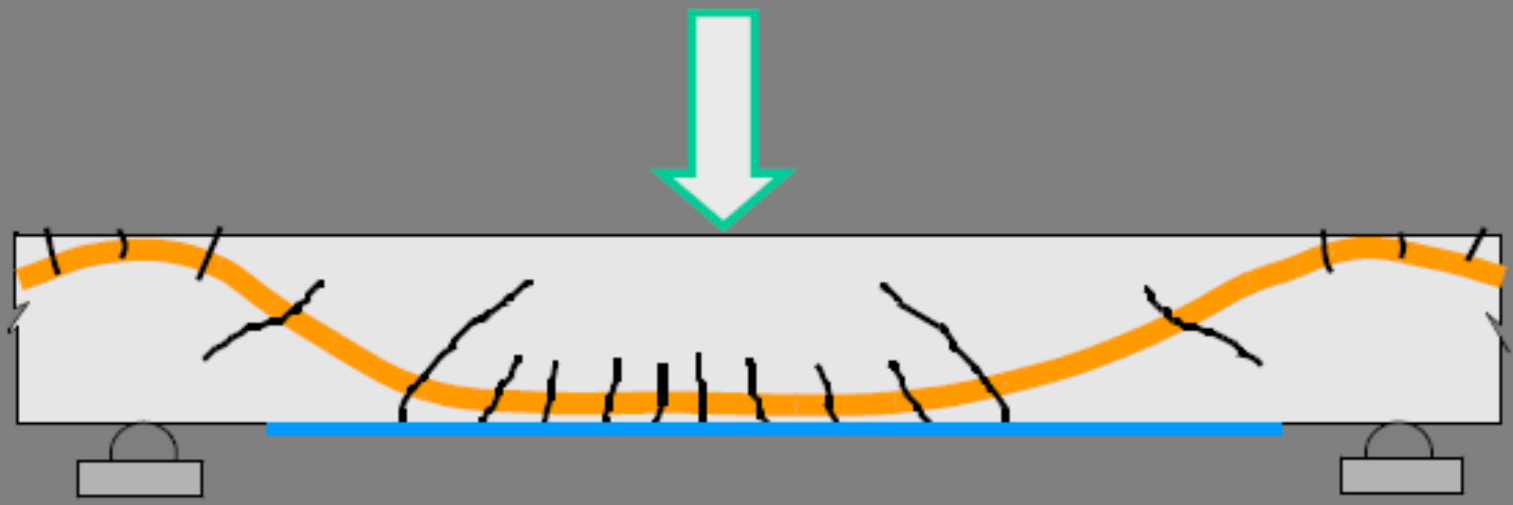
FRP Repair Strategy



Increase Service Load By:

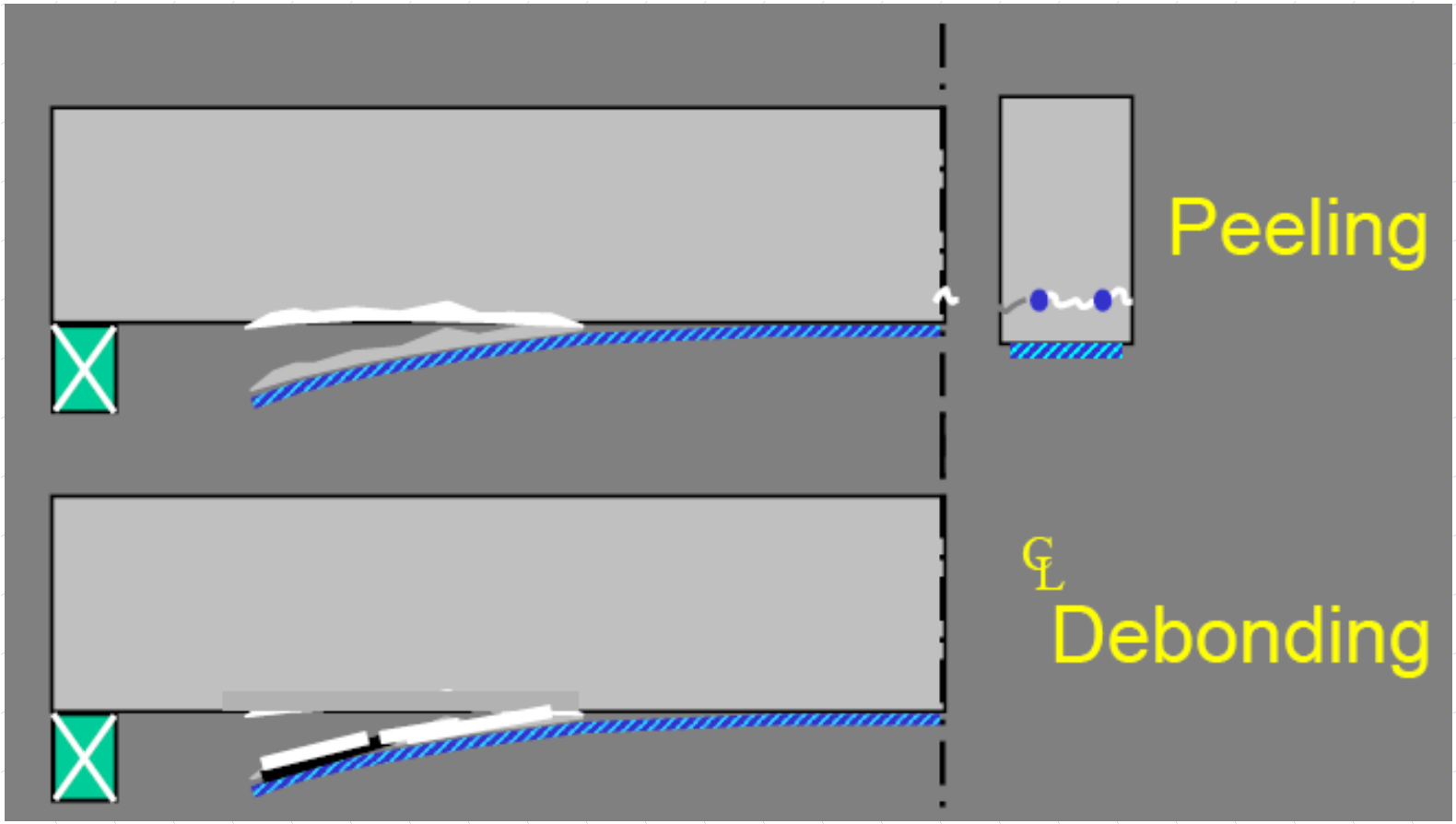
- Supplementing existing steel
- Limiting crack width
- Controlling crack distribution
- More cracks, tighter spacing & width

Failure Modes of FRP

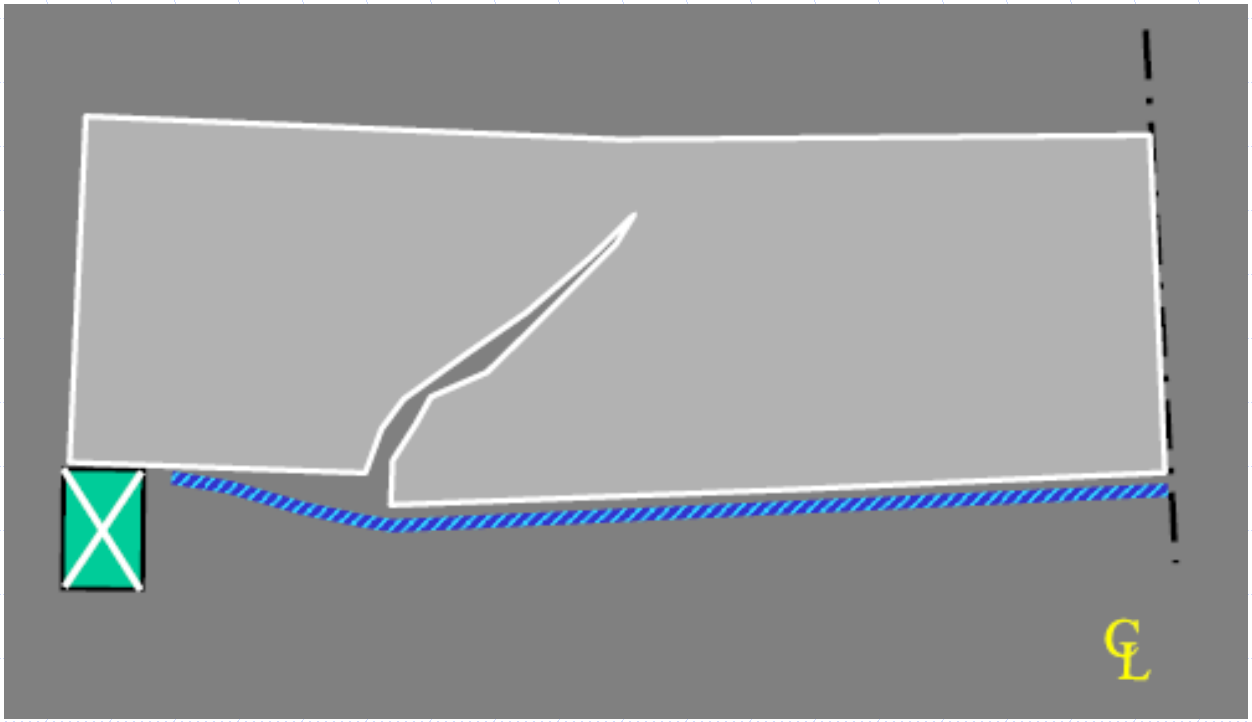


- Horizontal Shear or Debond
- Compressive Failure of Concrete
- FRP Sheet Rupture

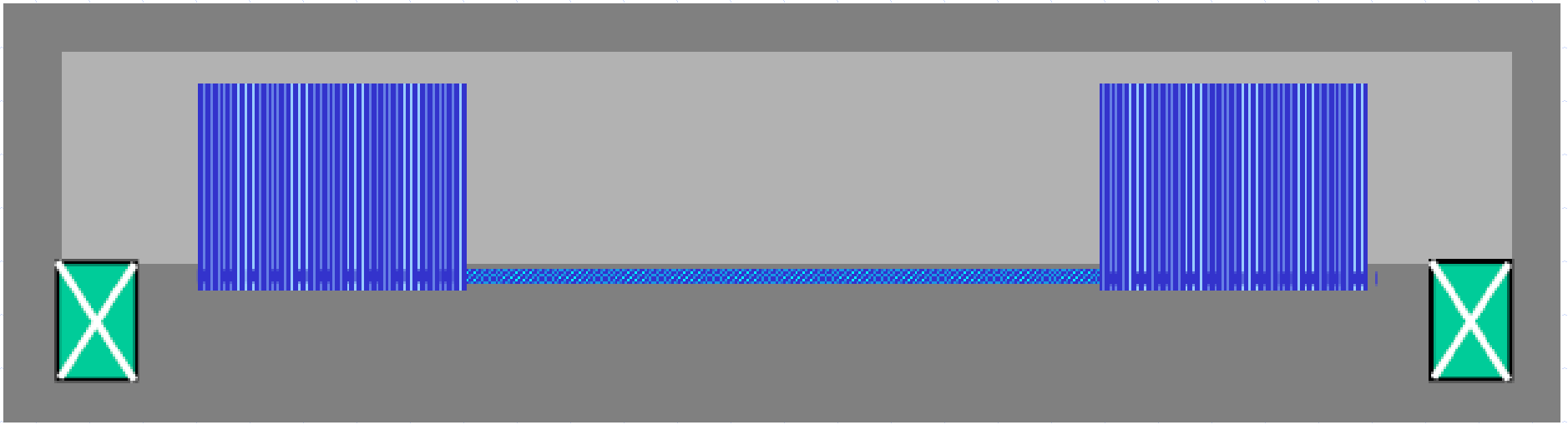
Horizontal Shear Failure



Beam Shear Delamination Failure



Detailing Guideline



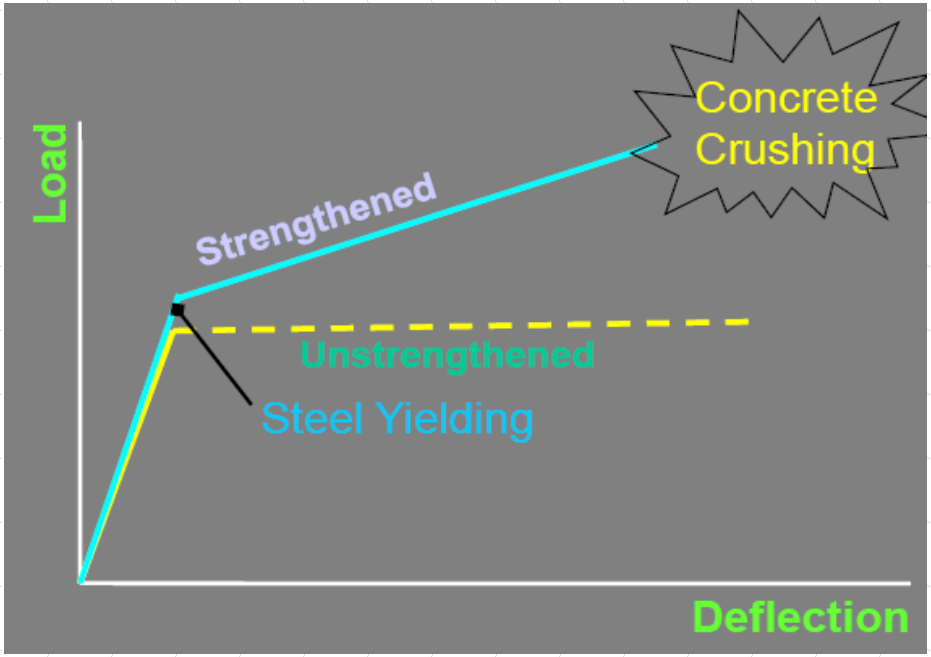
Failure Modes of FRP

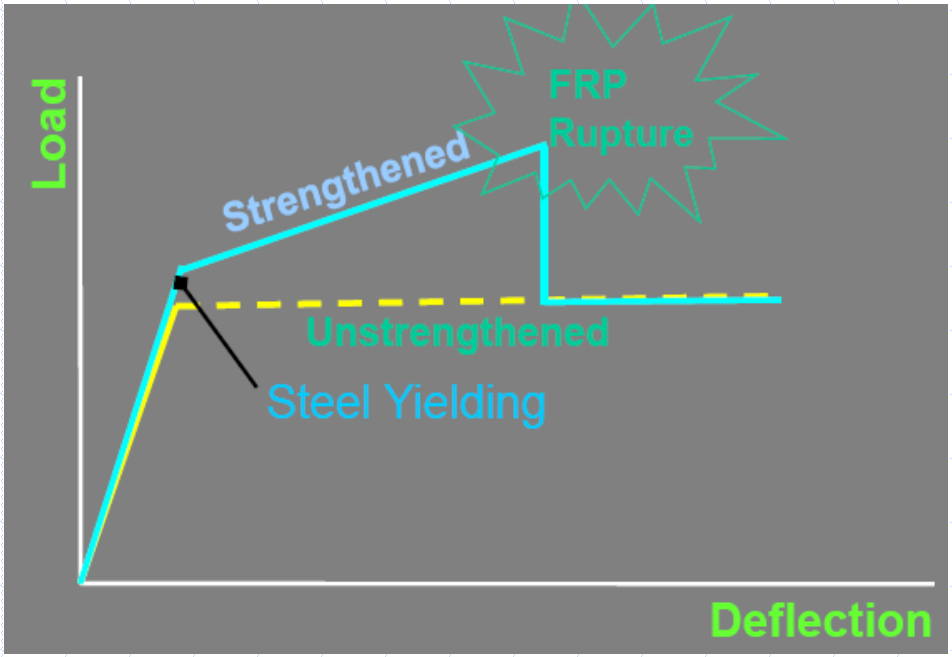
Ductile (Desirable)

- **Steel yielding** followed by concrete crushing
- **Steel yielding** followed by FRP rupture

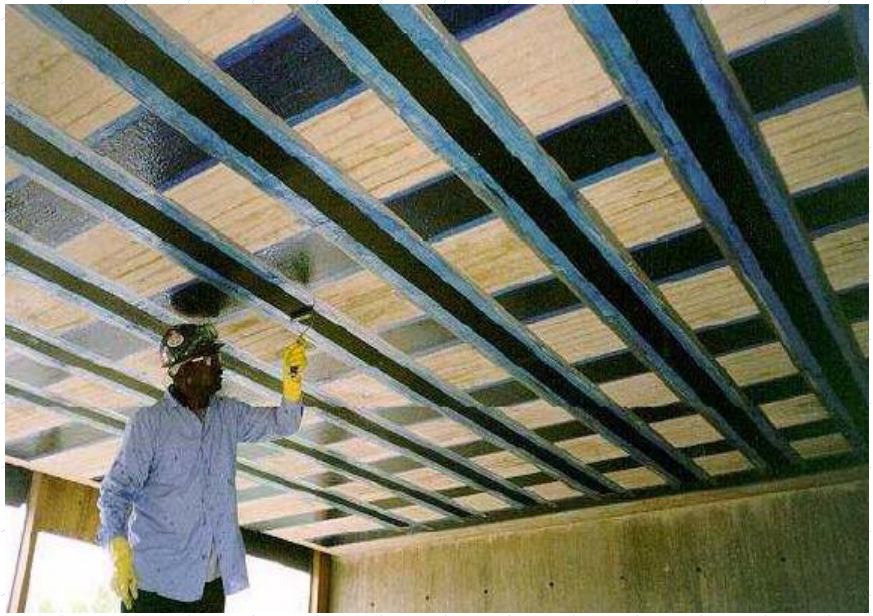
Brittle (Undesirable)

- **Concrete crushing** before steel yielding

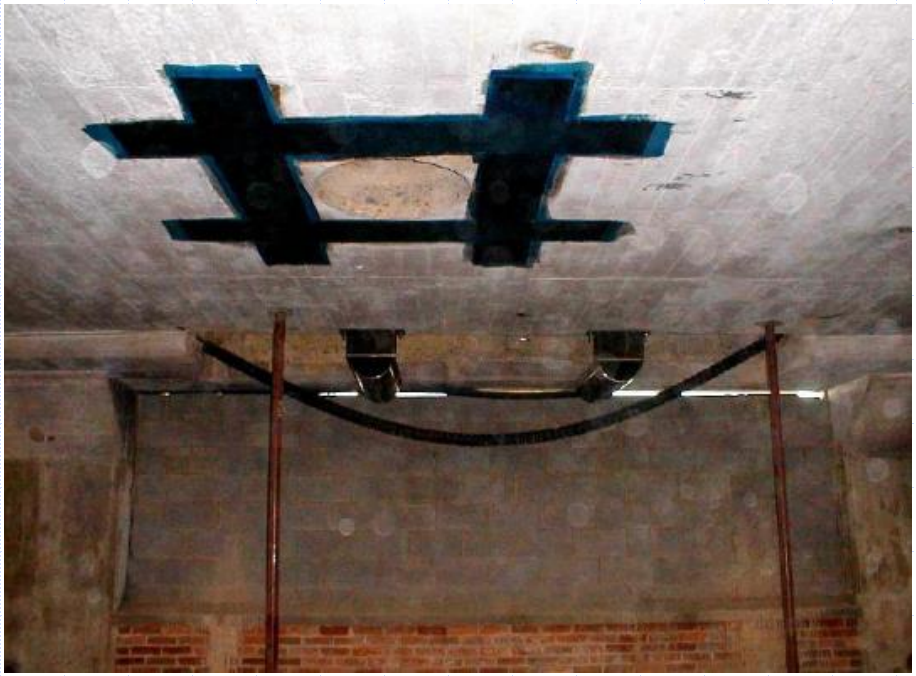




Case Studies of FRP Flexural Strengthening

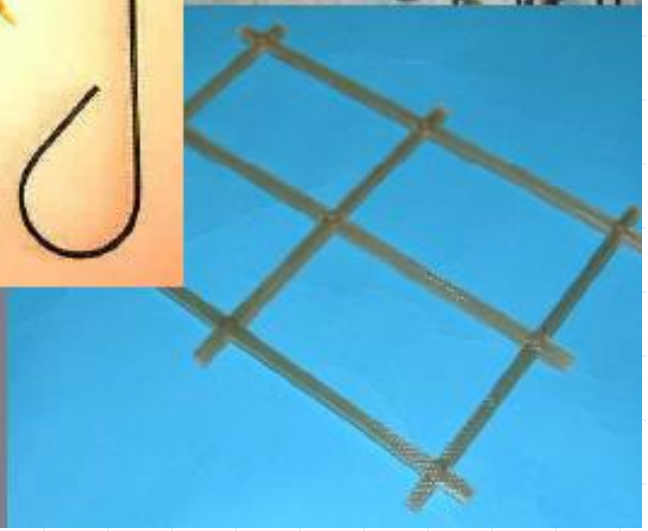


Case Studies of FRP Flexural Strengthening



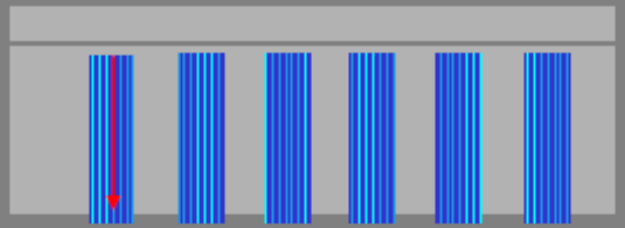
FRP Shear Reinforcement

- Pre-bent stirrups (open or closed)
- 2-D grids (NEFMAC)
- 3-D grids
- Bent-up bars
- Pre-formed spiral
- Thermo-plastic stirrups

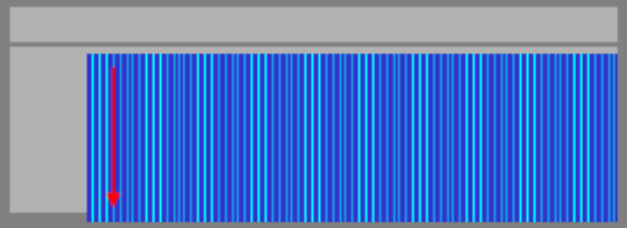


Shear Strengthening

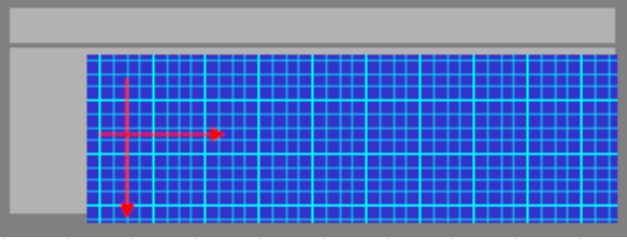
- Increase ϕV_n
- Account for all possible failure modes
- Simple Design Procedure



- Strips

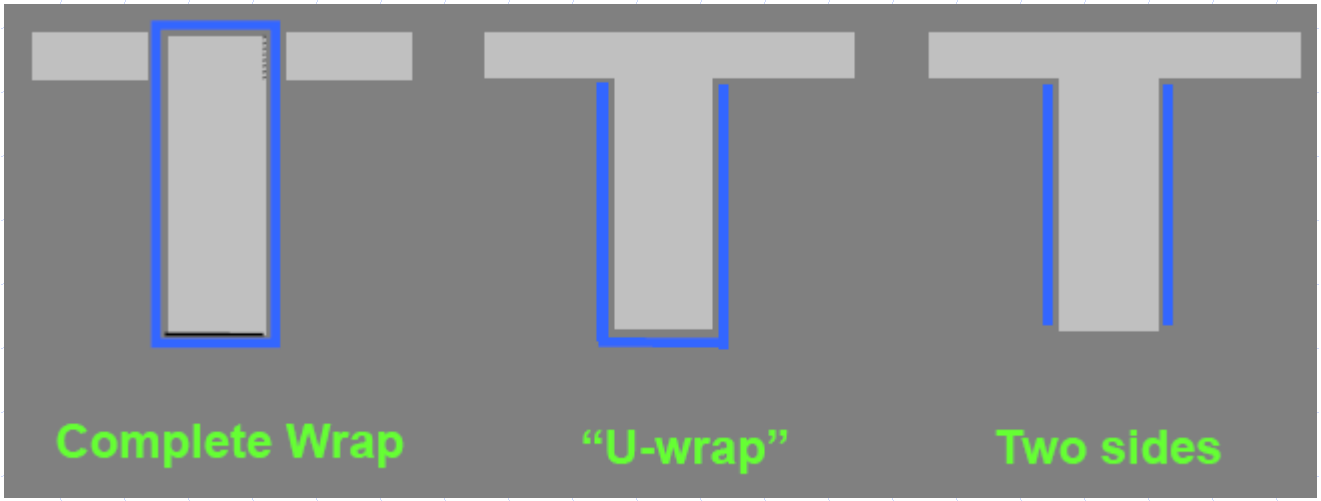


- Continuous



- 2 Directions (0/90)

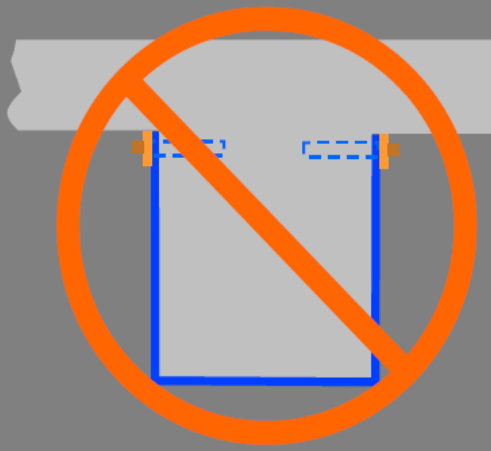
Shear Strengthening: Wrapping Scheme



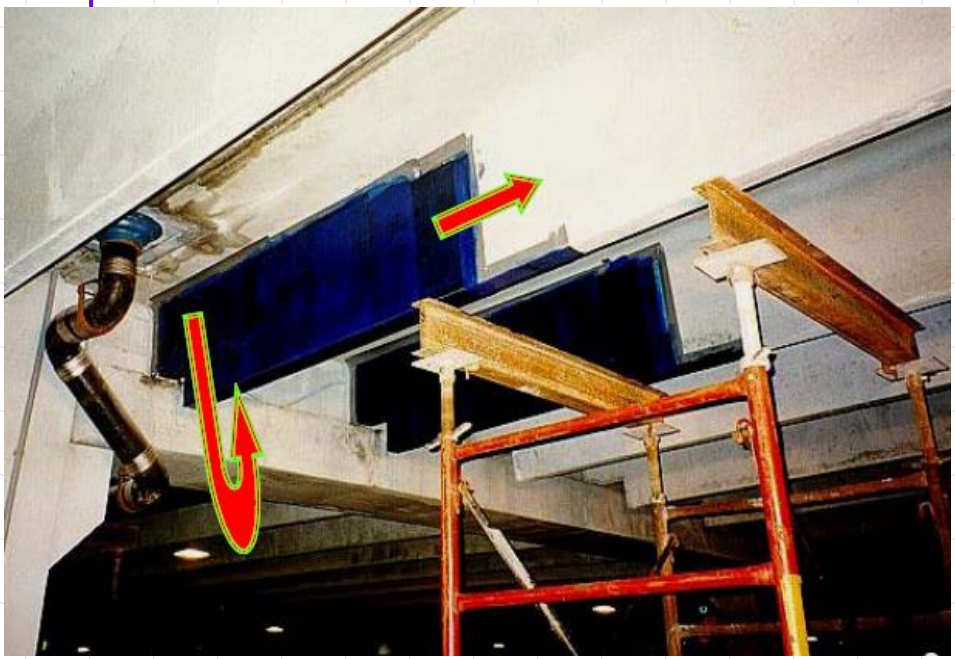
Possible shear failure modes

- Debonding of FRP sheet from substrate
- Loss of aggregate interlock (i.e., loss of V_c)
- FRP rupture due to stress concentrations

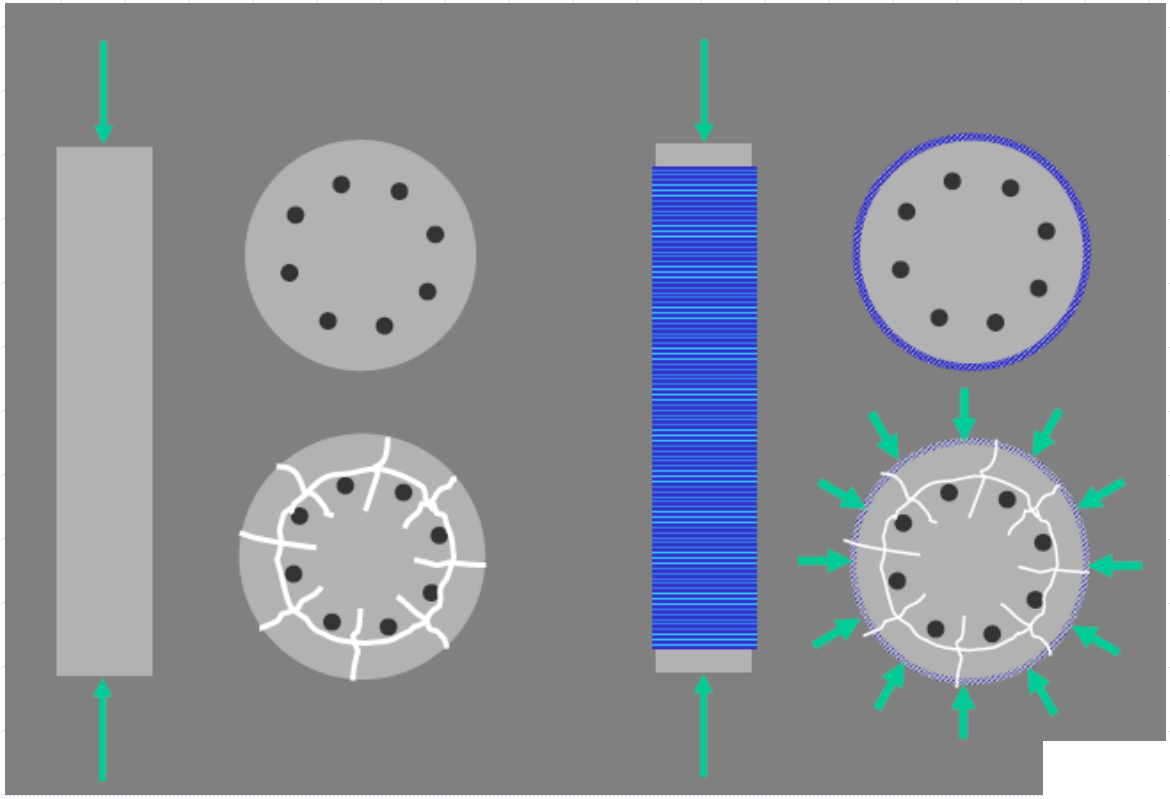
◆ Mechanical Fasteners…?



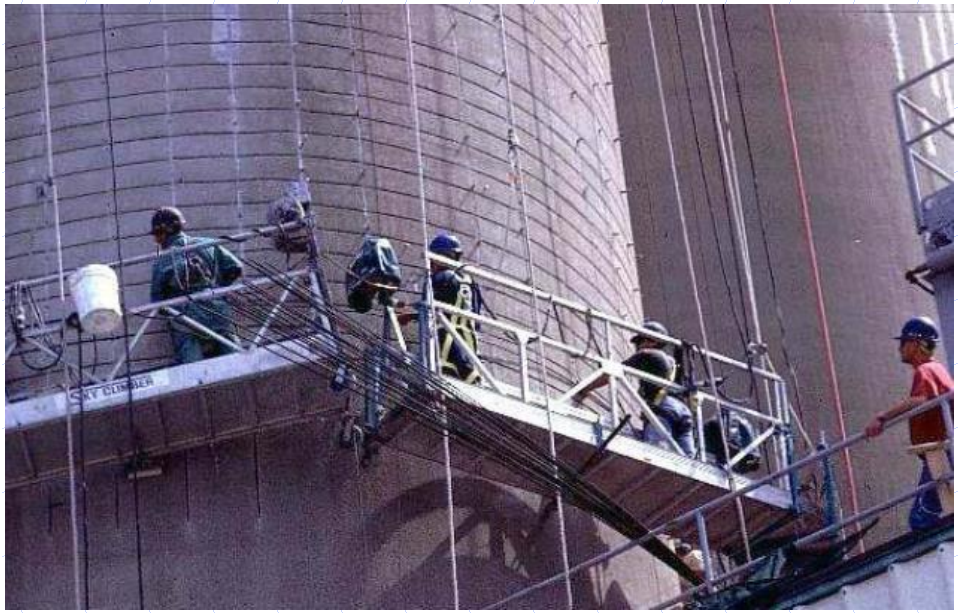
Case Studies of Shear Strengthening



Confinement Strengthening of Column



Near Surface Mounting: FRP Rods



Questions and Assignment