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Understanding FRP – Utilizing Carbon Fiber in Structural Repairs

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The Many Forms of FRP Repairs

- Column
- Post-tension
- Spandrel
- Vertical Shear Wall
- **Twin Tee**

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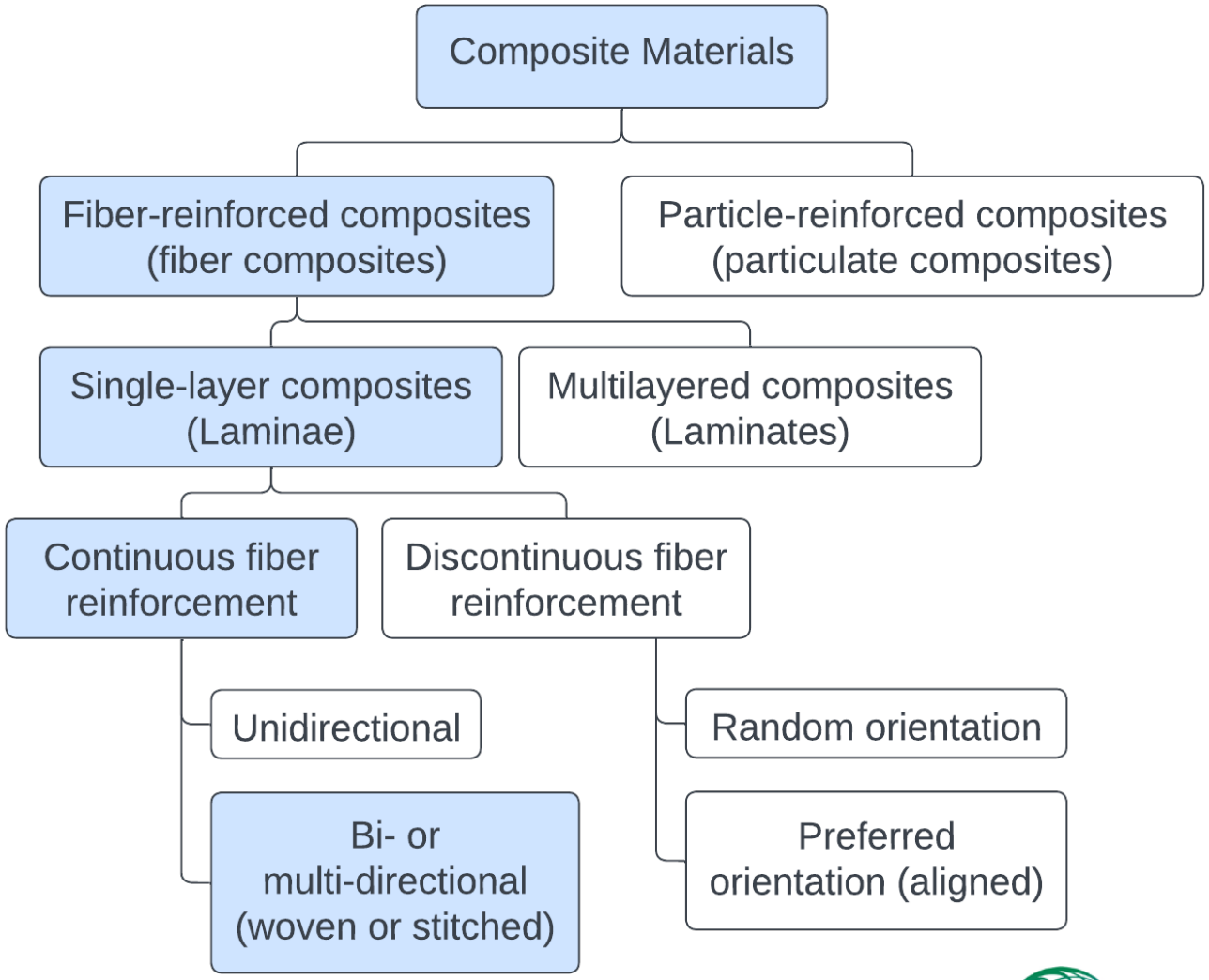
Types of FRP

- Glass
- Aramid
- Basalt
- **Carbon**



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Outline

- **Is FRP an appropriate repair?**
  - Importance of team
  - Enlist Engineer
  - Feasibility – engineering perspective
  - Benefits – contractor's perspective

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Project in Focus

- **Healthcare Facility**
  - 6 story - 3 below grade
  - Twin tee construction
  - Double helix
  - Horizontal/vertical concrete repairs, FRP reinforcement
  - High standards of functionality and cleanliness throughout project

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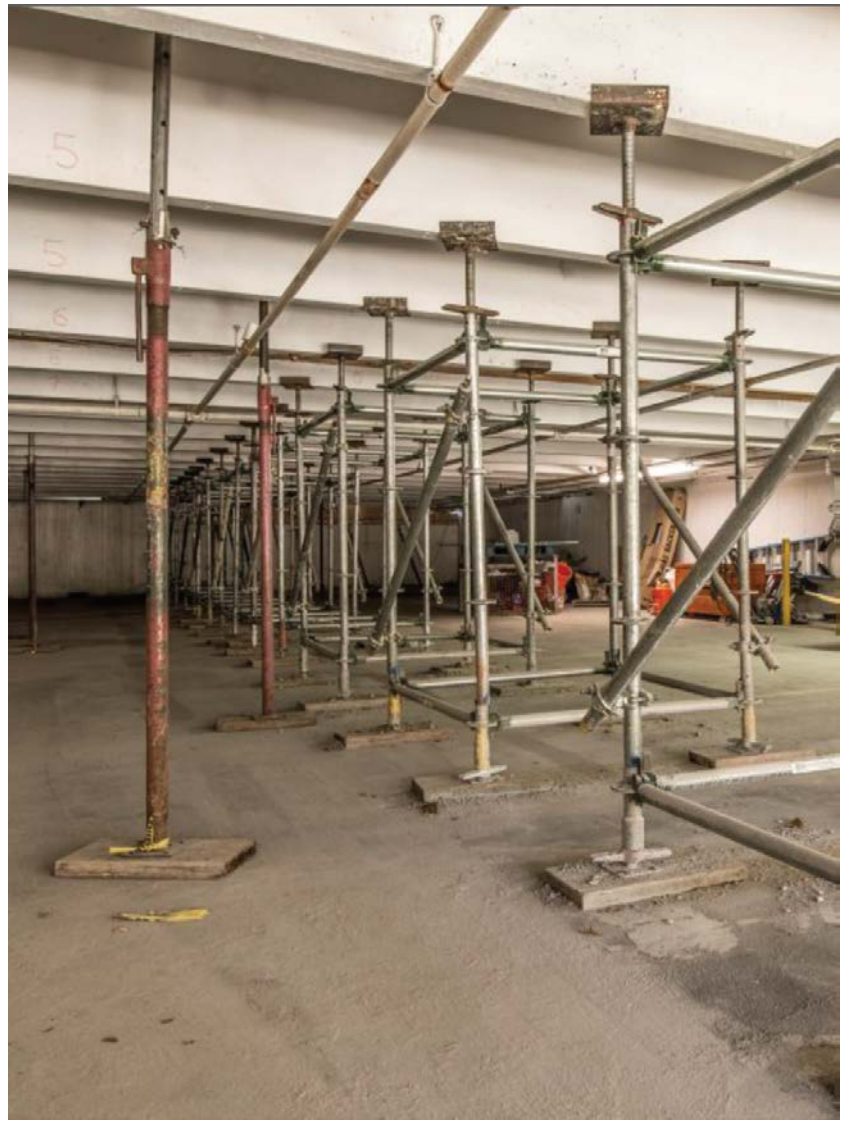
Shoring

- **Major impact to facility**
  - Cost
  - Lost revenue
  - Schedule
  - Aesthetic
  - Life safety



Investigation Phase

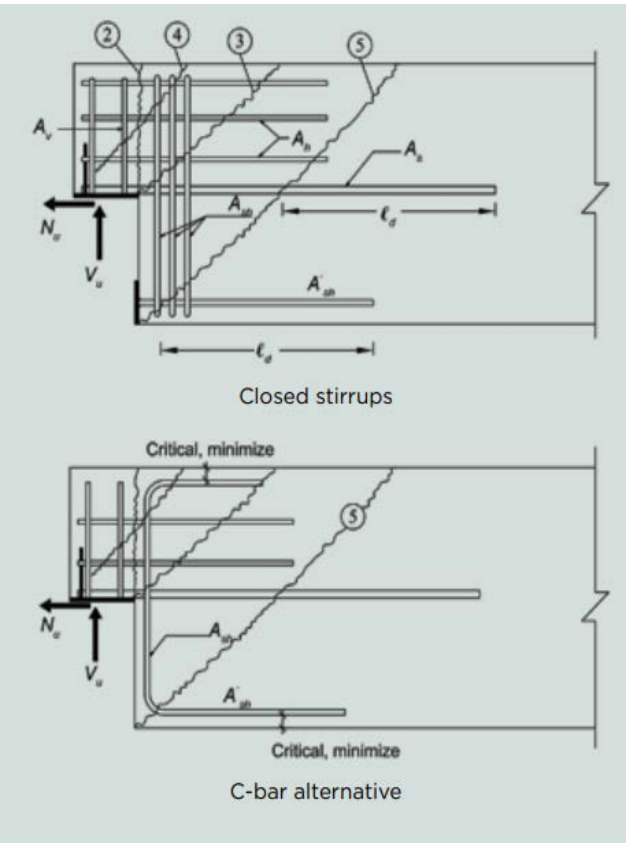
An Engineer's Perspective

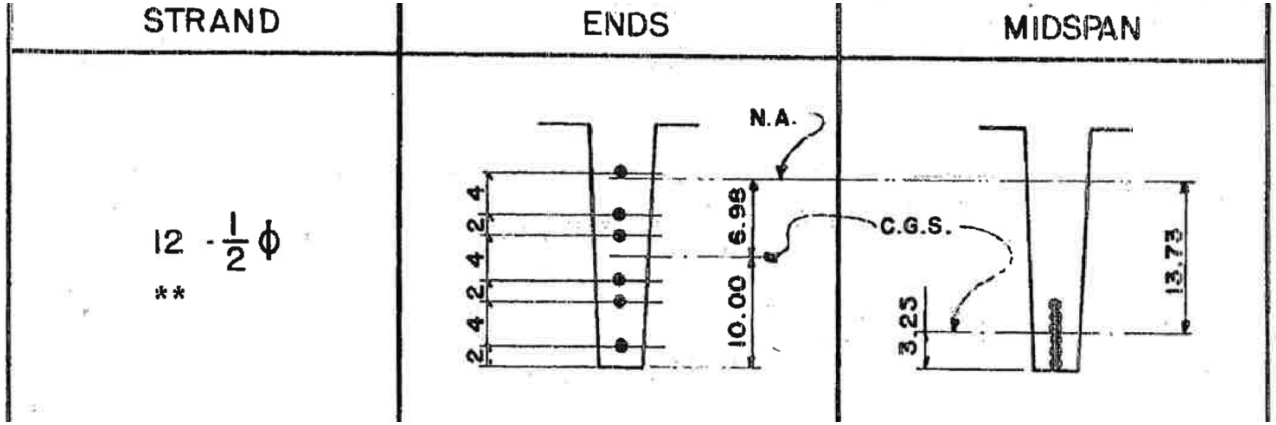
Work Item	Repair	General Location	Approximate Quantity	Unit
I-1	Precast concrete double-tee stem bearing end repairs	Underside of Level 3, 2, 1, B1, and B2	70	EACH
I-2	Double-tee stem end FRP u-wraps (18 square feet per wrap)	Underside of Level 3, 2, 1, B1, and B2	42	EACH

Investigation Phase

An Engineer's Perspective

- Original Design
- Sounding/NDT
- Select demolition





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Repair Options

- Concrete Repair only
- FRP
- Tee Stem Enlargement

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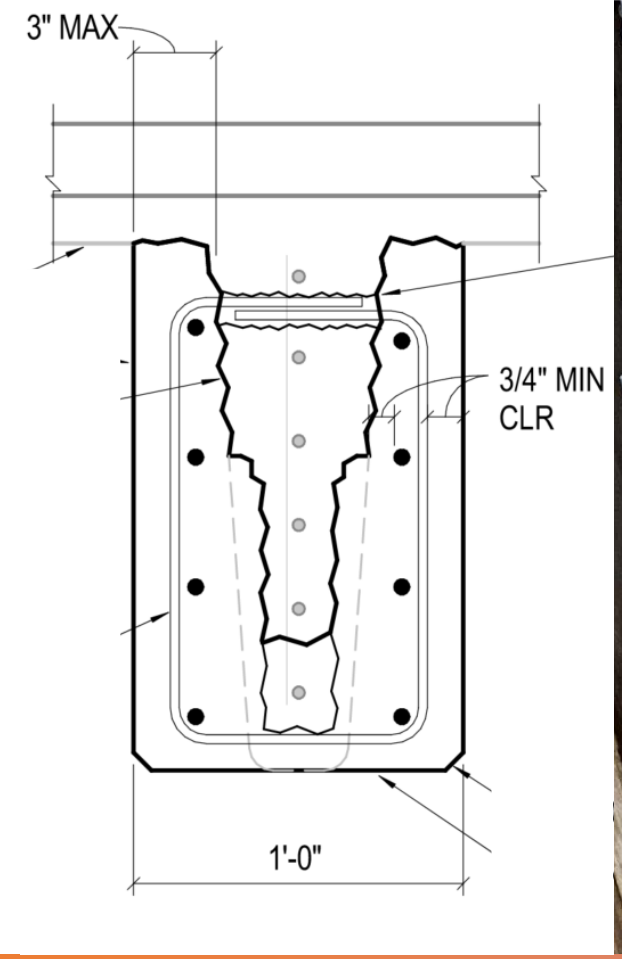

Tee Stem Enlargement

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Engineering Considerations - FRP

- Location of DT: strand patterns, live loads
- Dapped vs. non-dapped
- Number/length of strands exposed
- Damaged cross welds on WWR
- Fire load case

Carbon Fiber Reinforcement (FRP)

Engineering Considerations - FRP

ACI 562-21
ACI 440.2R-17

$$\phi R_n \geq 1.1D + 0.5L + 0.2S \quad (5.5.2a)$$

$$\phi R_n \geq 1.1D + 0.75L \quad (5.5.2b)$$

w/out FRP
should FRP
be damaged

Shear Capacity - Contribution due to concrete – $2\sqrt{(f'c)}$
Supplemental shear steel?

$$\phi_{ex} R_{ex} \geq (0.9 \text{ or } 1.2)D + 0.5L + 0.2S \quad (5.5.3)$$

w/FRP
Reduced material properties due to elevated temps.

Carbon Fiber Reinforcement (FRP)

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Engineering Considerations - FRP

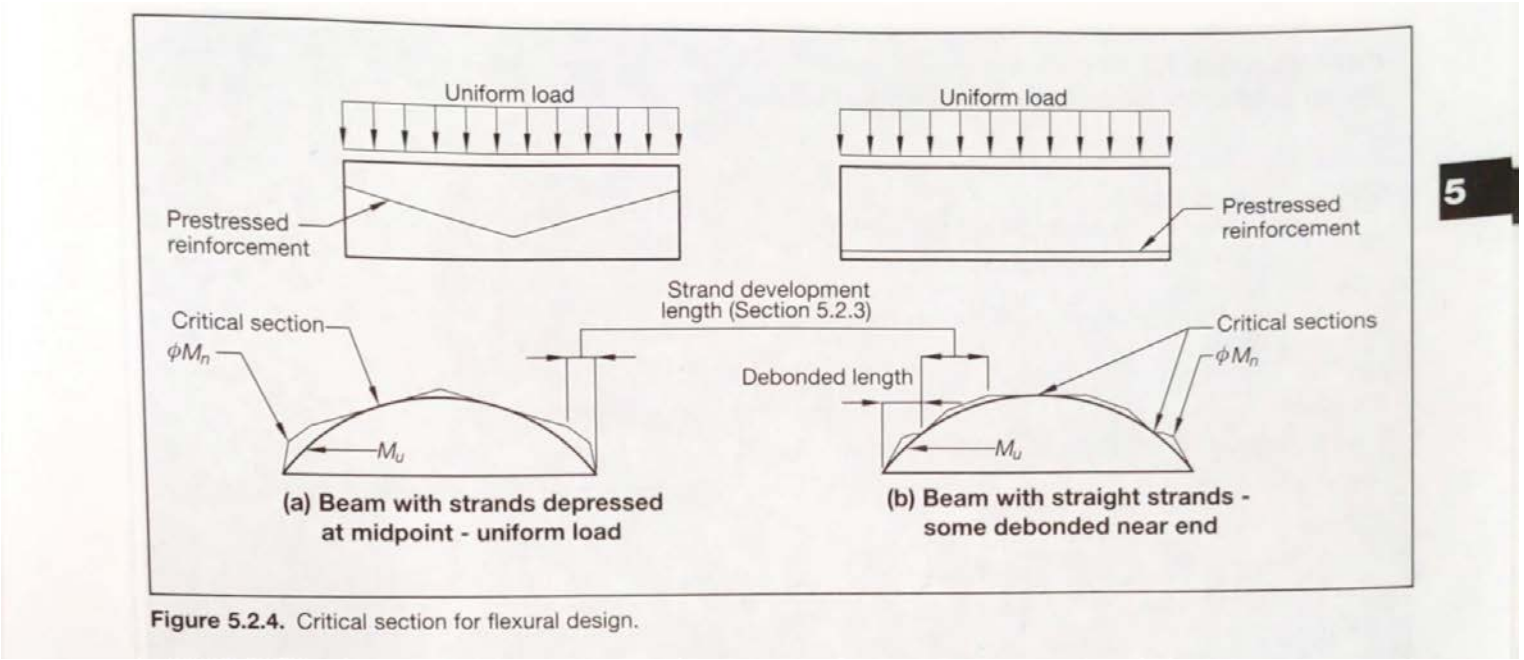

Figure 5.2.4. Critical section for flexural design.

5.2.1.6 Critical Section

For simply supported, uniformly loaded, prismatic nonprestressed components, the critical section for flexural design will occur at midspan. Where reinforcement is not uniform for the entire span, critical sections may occur at the bar cutoff locations. To reduce the end stresses at release for uniformly loaded prestressed components, some strands may be depressed near midspan or debonded for a length near the ends. For strands with a single-point depression, the critical section can usually be assumed at 0.41. For straight strands, the critical section will be at midspan. but **if some strands are debonded near the end, an additional critical section may occur near the end of the debonded length, as shown in Fig. 5.2.4.**

Carbon Fiber Reinforcement (FRP)

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Carbon Fiber Reinforcement (FRP)

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Identifying Pros & Cons

A Contractor's Perspective

- Pricing
- Schedule
- Testing

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Pricing

- Enlargement is often twice the cost of FRP
- FRP offers labor reduction

Identifying Pros & Cons

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Schedule

- Front end FRP design longer duration
- FRP installation roughly ⅓ of enlargement

Identifying Pros & Cons

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Testing

- Pull off values
- Breaks of host material
- Breaks of prepackaged repair mortar

Identifying Pros & Cons

Benefits of Implementing Carbon Fiber Reinforcement (FRP)

- Corrosion Mitigation
- Immediate Strength
- Low Profile
- Sustainability / Longevity
- Discreet

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Maintaining Functionality During Construction

- Quicker Test Results
- Reduced Laydown Area

Questions?

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