FIBER REINFORCED POLYMERS IN CONSTRUCTION

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Overview

- What are FRP (Fiber Reinforced Polymers)?
- Typical Uses and Applications of FRP
- Conventional Methods for Retrofit/Repair
- FRP Installation
- FRP Applications
- Advantages of FRP

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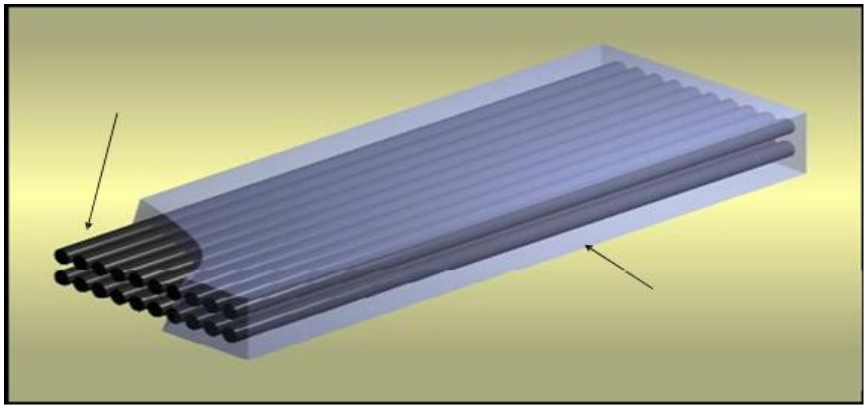
What Are Fiber Reinforced Polymers?



- FRP is a matrix consisting of carbon or glass fibers encapsulated in a polymer or resin.
- The fibers provide the tensile strength in the direction of their orientation
- The resin provides stability, shear strength and bonding of the FRP to the substrate.

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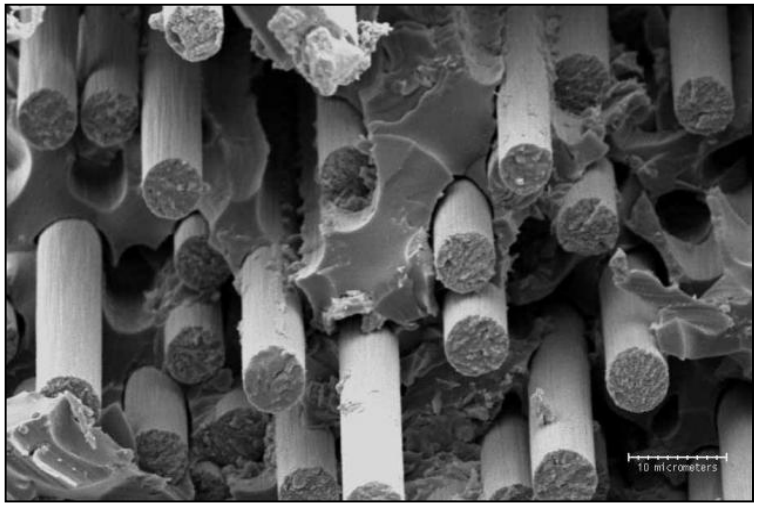
What Are Fiber Reinforced Polymers?



Carbon, Glass, Aramids, Basalt, Other Natural Fibers

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What Are Fiber Reinforced Polymers?

- Sheets and Fabrics
- Pre-cured Laminates
- Rebar
- Grids
- Shells
- PT Strands
- Structural Shapes

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What Are Fiber Reinforced Polymers?

Wet Lay-up Systems

Epoxy is mixed on site and the fabrics are saturated with the resin, applied to the structure and allowed to cure at ambient temperature.

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What Are Fiber Reinforced Polymers?

Pultruded FRP Plate

A high strength pre-cured carbon fiber plate that is bonded to the structure or may be embedded in a saw cut

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What Are Fiber Reinforced Polymers?

FRP Bars

FRP Grid

Stay-In-Place Forms

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Typical Uses and Applications of FRP

FRP HAS BEEN EXTENSIVELY USED FOR A VARIETY OF SEISMIC AND STRUCTURAL RETROFIT / REHABILITATION APPLICATIONS IN LIEU OF CONVENTIONAL METHODS:

1. SEISMIC RETROFIT

    A. INCREASE COLUMN DUCTILITY

    B. INCREASE SHEAR & FLEXURAL CAPACITY

    C. IN-PLANE & OUT-OF-PLANE STRENGTHENING OF WALLS

2. INCREASED LOAD DEMANDS (FLEXURE/SHEAR IN BEAMS & SLABS)

    A. EXISTING FLOOR SLABS WITH OCCUPANCY CHANGE

    B. NEW MECHANICAL EQUIPMENT, RAISED FLOORS ETC.

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Typical Uses and Applications of FRP

3. DETERIORATION OF EXISTING MEMBERS

   A. CONCRETE SPALLING REDUCING SECTION SIZE

   B. REINFORCEMENT CORROSION CAUSING REDUCTION IN CAPACITY AND INCREASING INSTABILITY

   C. DAMAGE TO NON-PRIMARY ELEMENTS UNDER SEISMIC LOADING

4. BUILDING ENVELOPES - CRACKED GFRC, PRECAST PANELS, MODIFICATIONS IN CONCRETE TILT-UP STRUCTURES

5. BASEMENT WALLS BOWING & CRACKING DUE TO RETAINED EARTH LOADING

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Typical Uses and Applications of FRP

6. INFRASTRUCTURE
    A. BRIDGE COLUMNS, BENTS, GIRDERS, SLABS
    B. WHARF PIERS, GIRDER, SLABS
7. NON-STRUCTURAL
    A. CRACKED, CORRODED PIPES AND TANKS
    B. DAMAGED FOUNDATIONS ETC.

USES OF FRP FOR NEW CONSTRUCTION ARE ALSO GROWING, ESPECIALLY WITH GFRP REINFORCEMENT AND STAY-IN-PLACE FORMS

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Conventional Methods for Retrofit/Repair

1. ADD REINFORCEMENT TO THE SECTION AND INCREASE THE SIZE OF THE MEMBER (E.G. CONCRETE OR STEEL JACKETING).

2. NEW STEEL MEMBERS TO INCREASE LOAD-CARRYING CAPACITY

3. BOLTED STEEL PLATES TO MEMBER SURFACES

4. USE SOME TYPE OF EXTERNAL POST-TENSIONING

5. FOR SEISMIC UPGRADES OF WALLS:

    A. SHOTCRETE FOR IN-PLANE & OUT-OF-PLANE LOADS

    B. SUPPORTING STEEL STRUCTURE FOR OUT-OF-PLANE LOADS

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Conventional Methods for Retrofit/Repair

- NOT FEASIBLE WITHIN OCCUPIED FACILITIES DUE TO CRITICAL ONGOING USE OF THE FACILITY
- GREAT IMPACT ON SCHEDULE AND COST
- MAY AFFECT THE FUTURE USE OF THE SPACE DUE TO INCREASED MEMBER SIZES
- DIFFICULT TO ACHIEVE SINCE HEAVY MATERIAL MAY NEED TO BE TRANSPORTED TO HARD-TO-ACCESS LOCATIONS LIKE CEILING SPACES, BASEMENTS, ETC.
- EXISTING CORROSIVE ENVIRONMENTS MAY MAKE TRADITIONAL MATERIALS AN INAPPROPRIATE CHOICE

FRP Installation

Repair of Structural Member

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FRP Installation

Surface Preparation

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FRP Installation

Priming the Surface

To promote adhesion and to prevent the surface from drawing resin from the FRP, an epoxy primer is applied with a roller or brush. The primer is allowed to soak in for approximately 15 min.

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FRP Installation

Apply Putty

A high viscosity adhesive paste is applied when necessary to fill voids and bugholes and to transition any offsets.

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FRP Installation

Cut the FRP Fabric

In a clean area away from the resins, the fabric is carefully measured and cut to the required lengths. The cut fabric is marked and stored in a clean dry area.

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FRP Installation

Saturate the FRP

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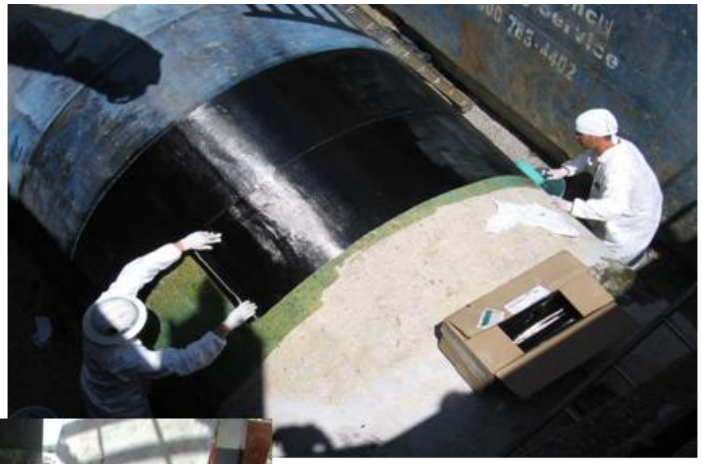
FRP Installation

Install FRP



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FRP Installation

Final Finish

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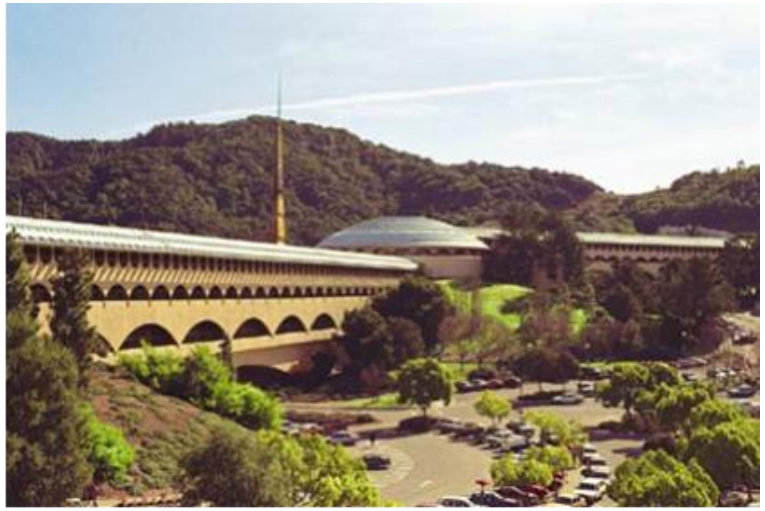
FRP Applications – Historic Buildings

Completed



Marin County HOJ, San Rafael, CA
Concrete shear wall strengthening, diaphragm continuity

Unitarian Church, Oakland, CA
URM walls out of plane strengthening

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FRP Applications – Historic Buildings

Completed

Squatter's Pub, Salt Lake City, UT
URM walls in plane and out of plane strengthening

Old County Courthouse, Redwood City, CA, diaphragm wall to wall shear transfer

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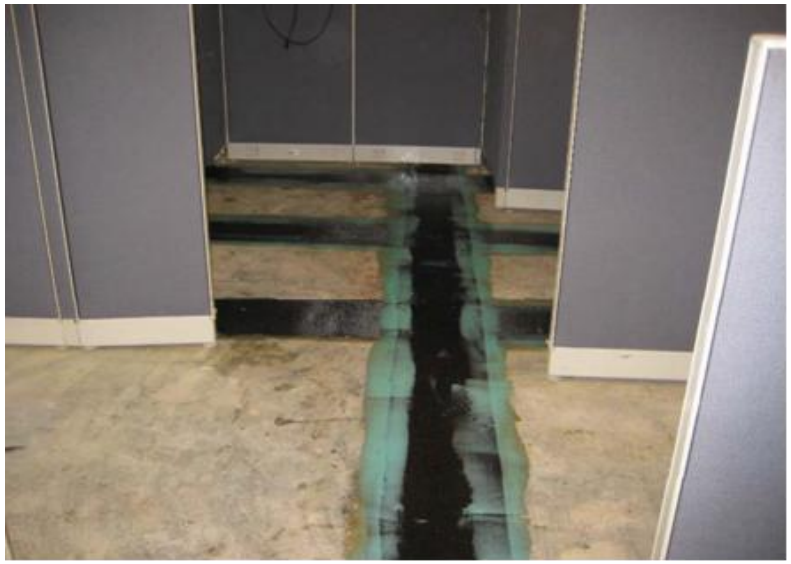
FRP Applications – Buildings

Slab strengthening (ceiling tiles removed grid in place)



Slab top strengthening for negative moment

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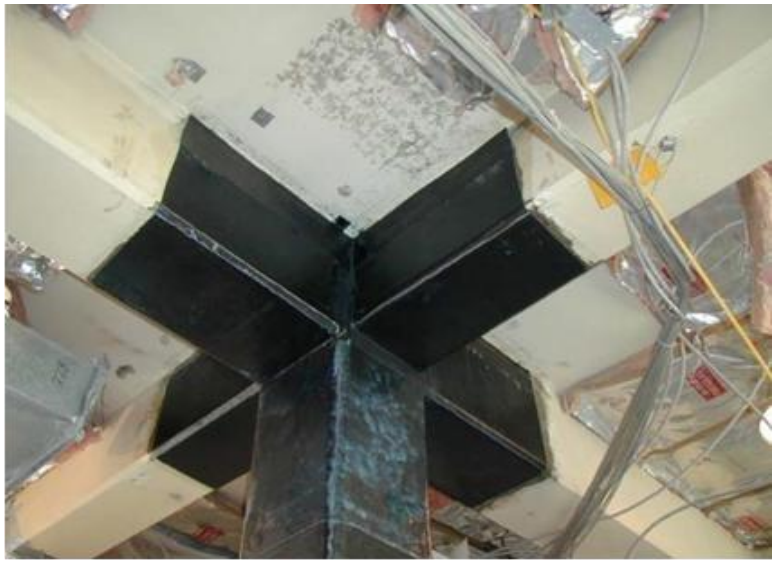
FRP Applications – Buildings



Beam column joint

Short column retrofit

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FRP Applications – Buildings

Shear wall in plane retrofit

Wall end confinement

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FRP Applications – Buildings

Shear wall in plane retrofit

Concrete deep beam and columns

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FRP Applications – Buildings

Column Retrofit

Column Retrofit

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FRP Applications – Buildings

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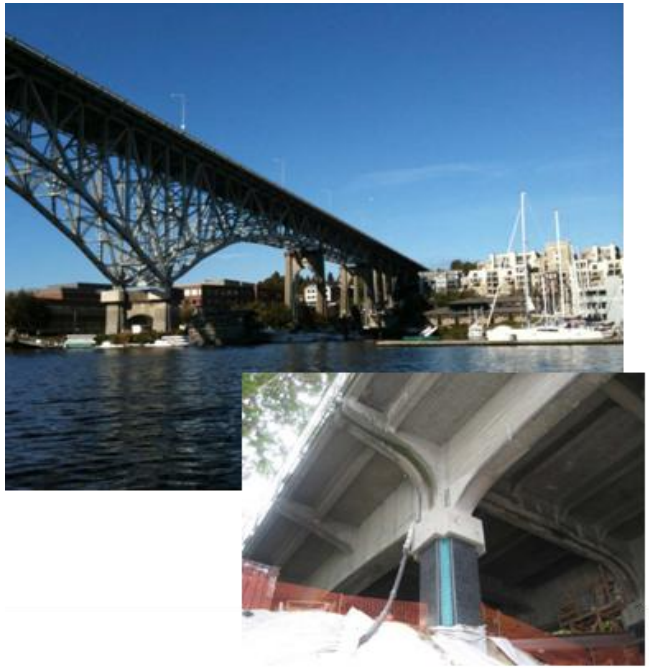
FRP Applications – Bridges



Aurora Bridge, Seattle, WA
pier retrofit

Rogue River Bridge, OR
Archand strut retrofit

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FRP Applications – Bridges

Evans Creek Bridge, OR
girder strengthening

BART West Oakland, CA
elevated station columns retrofit

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FRP Applications – Industrial

Tesoro Refinery
concrete structural retrofit

Valero Refinery
concrete structural retrofit

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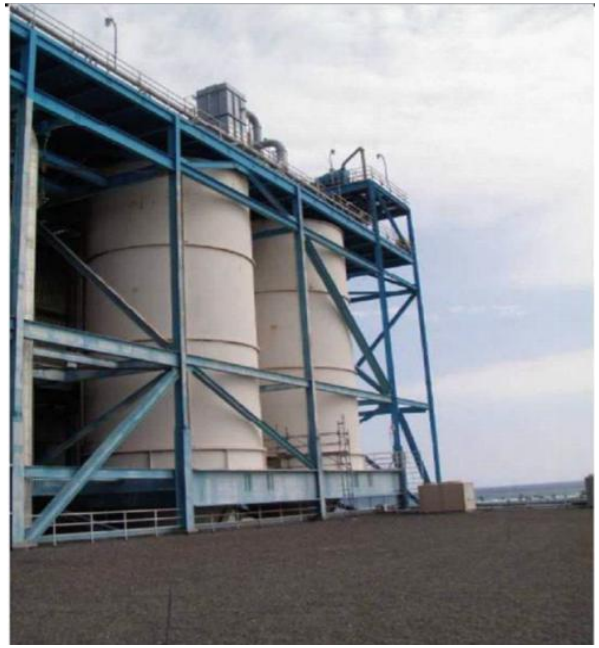
FRP Applications – Industrial



Coal Silos

Process Water Tank
Copper Mining

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FRP Applications – Industrial

Furnace Exhaust Duct

Copper Tank House
Support Columns

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FRP Applications – Blast /ATFP

Masonry Wall Without FRP

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FRP Applications – Blast /ATFP

Masonry Wall With FRP

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FRP Applications – Blast /ATFP

Concrete Column Without and With CFRP Live Blast

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FRP Applications – Blast /ATFP

Concrete Column With and Without CFRP
UCSD Blast Simulator

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Advantages of FRP

Axial Compression & Ductility

- WRAPPING WITH FRP CAN PROVIDE CONFINEMENT TO A CONCRETE COLUMN
- CONFINEMENT CAN:
    - INCREASE COMPRESSIVE STRAIN AT WHICH FAILURE OCCURS
    - PROVIDE A CORRESPONDING INCREASE IN CAPACITY
    - DELAY BUCKLING OF LONGITUDINAL STEEL
    - PROVIDE CLAMP IN GOFLAP SPLICES

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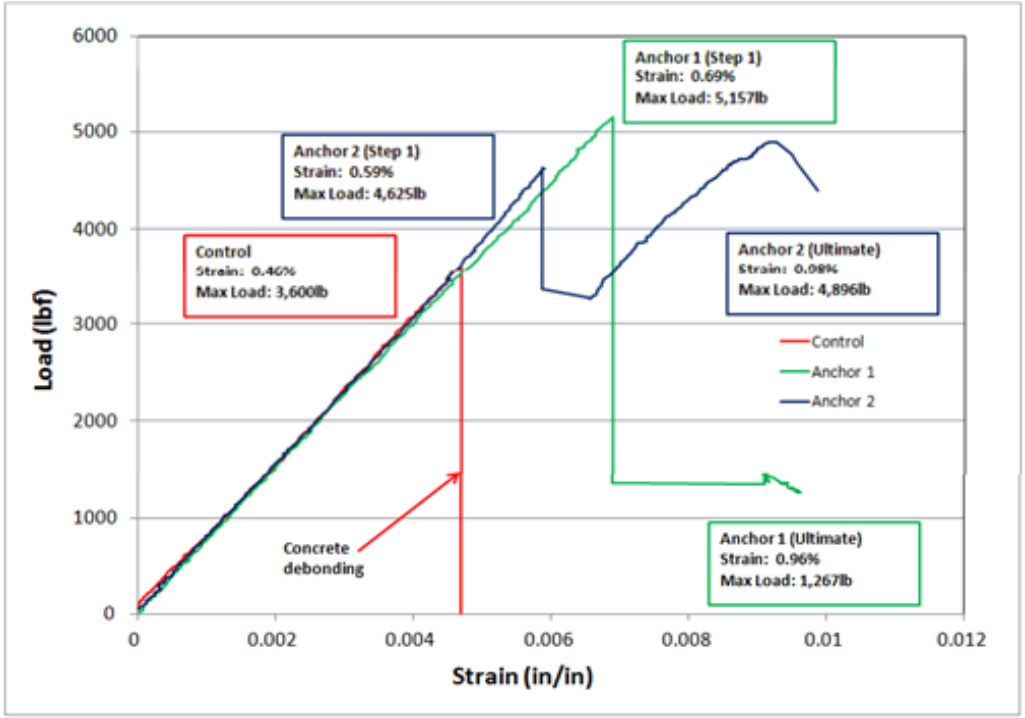
Advantages of FRP

Design Methodology with FRP

FRP Anchorage



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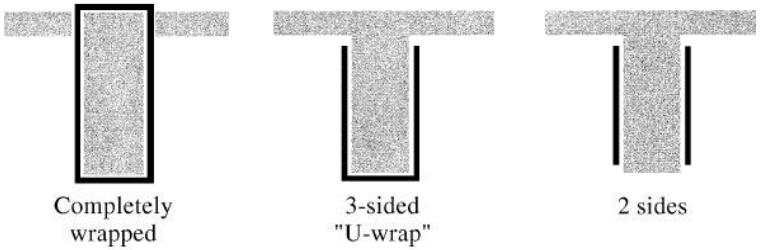
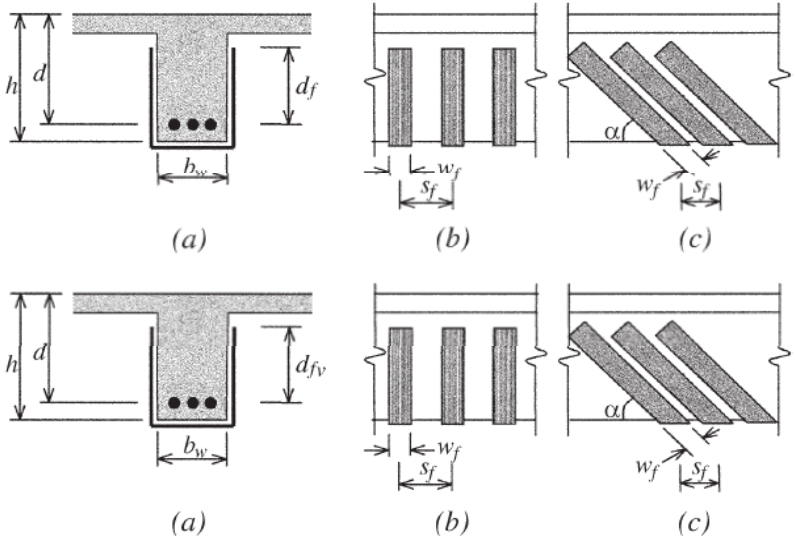
Advantages of FRP

Application Methodology with FRP



Typical wrapping schemes for shear strengthening



Illustrations of the dimensional variables used in shear strengthening

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Final Remarks

- THE USE OF FRP FOR A WIDE-RANGE OF APPLICATIONS HAS GAINED WIDE-SPREAD ACCEPTANCE ALL OVER THE WORLD
- FRP MATERIALS FORM AN ESSENTIAL TOOL IN THE TOOL-KIT OF STRUCTURAL ENGINEERS AND CONTRACTORS
- IF USED APPROPRIATELY, FRP CAN PROVIDE COST-EFFECTIVE SOLUTIONS TO REPAIRS THAT MAY BE UNFEASIBLE WITH CONVENTIONAL MATERIALS
- THE BEST APPROACH IS TO GO BACK TO BASIC ENGINEERING PRINCIPALS SUCH AS PROPER DEVELOPMENT OF THE MATERIAL, USE OF THE APPROPRIATE LOAD AND STRENGTH REDUCTION FACTORS, DUCTILE DETAILING
- RELIABLE FIRE RATING FOR FRP IS STILL UNDER DEVELOPMENT

We Are Ready To Help

- ASSIST WITH IDENTIFYING POTENTIAL APPLICATIONS
- REVIEW CURRENT PROJECTS TO SEE IF FRP COULD BE A COST EFFECTIVE SOLUTION IN LIEU OF CONVENTIONAL METHODS
- PROVIDE PRELIMINARY ENGINEERING SUPPORT TO DEVELOP DESIGN
- PROVIDE ASSISTANCE WITH PUTTING TOGETHER SPECS
- PROVIDE COMPLETE DESIGN-BUILD SOLUTIONS

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Discussion / Questions

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