TECHNICAL BULLETIN 8

FIBER REINFORCED POLYMER COMPOSITE STRENGTHENING SYSTEMS

INTRODUCTION

1. Fiber-reinforced polymer (FRP) composites are constructed from high strength, high modulus fibers and a liquid resin or matrix that cures to form a hardened solid structural material. These materials are often used to construct commercial and military aircraft, boats, and various sporting goods (bicycles, fishing rods, skis and snowboards, among others). The fibers used with these materials are most commonly:
   - Carbon Fiber of various strengths and stiffness's
   - Glass Fiber of various types (most commonly E-glass or S-glass)
   - Aramid Fiber (Kevlar® is a widely known brand of aramid fiber)

2. The resins used to construct these materials can be of many different types but are generally:
   - Epoxy Resin (most often used)
   - Polyester Resin
   - Vinyl ester Resin

3. FRP composite reinforcing bars for concrete and FRP structural members are in use in the construction industry in specialty applications typically to supplement existing reinforcement or structure.

4. FRP composite systems are most often used on reinforced concrete, masonry, and wood structures.

5. The focus of this bulletin in on the most common construction application, the use of FRP composites for strengthening existing structures. Generally, FRP composite strengthening systems are used for one the following purposes:
   - Strengthen structures in either the flexural and shear zones.
   - Provide confinement to compression members

FEATURES AND BENEFITS

1. FRP syatems can be utilized for the following:
   - Increase load bearing capacities
   - Seismic upgrades
   - Restoring load bearing capacities for structures that have experienced deterioration of original reinforcing.

2. Advantages
   - Does not add mass to the structure.
   - Minimal down time. End service interruption.
   - Cost effective application.
   - No loss of head room or space.
   - Ease of application.

TYPES OF FRP COMPOSITE SYSTEMS

Laminate Systems:
Laminate systems consiste of a manufactured composite material that are delivered to the jobsite as a thin, flat plate (usually less than 1/16" thick and 2 to 6 inches wide). The laminates are cut to the desired length in the field and applied to the structure with a system-specific epoxy adhesive. This system is typically applied to flat surfaces.

Laminate systems are uni-directional systems of the following types:
- CFRP (carbon fiber reinforced polymer) are the most common
- GFRP (glass fiber reinforced polymer)

FABRIC SYSTEMS:
Fabric systems are comprised of a fabric and system specific resin system (most commonly epoxy). The fabrics are constructed of individual fibers that are brought together in "bundles" called tows or rovings and woven to form a fabric sheet. The dry fabric sheet delivered to the jobsite and is saturated in the field using system-specific resins to form the composite system. The in-field fabrication allows for conformal wrapping of round, rectangular, or irregular shapes.

Fabric systems can be unidirectional (primary fibers all along the length of the fabric) or can be woven with fibers in multiple directions (bidirectional or multiaxial fabrics). Typical fabric types are as follows:

- Unidirectional and Bidirectional Carbon Fiber Fabrics
- Unidirectional and Bidirectional Glass Fiber Fabrics
- Aramid Fiber Fabrics also exist

NEAR SURFACE MOUNTED SYSTEMS:
Near surface mounted systems consist of a manufactured composite bar or strip that is installed with and epoxy adhesive into shallow grooves cut into the substrate. The bars are typically small enough to be installed in a groove that is roughly ½" wide and ½" deep. These systems are usually used as topside reinforcement on a surface that will receive traffic or wear.

Near Surface Mounted (NSM) systems are commonly one of the following types:
- CFRP bars or strips
- GFRP bars or strips

TYPICAL USES OF FRP

Composite Strengthening Systems
1. Increase load bearing capacities of existing structures for new or increased loads
2. Seismic retrofits of existing structures
3. Restoring load bearing capacities in damaged or deteriorated structures
4. Blast upgrades

INSTALLATION CONSIDERATIONS

Surface Prep:
Surface must be clean, dry, and sound with all surface defects removed or repaired. Refer to manufactures printed specifications to determine the surface profile needed for best bond.

Fabric applications require that corners be rounded and all sharp edges removed prior to installation.

APPLICATION:
Laminate strip:
1. Cut strips to desired length and clean prior to the application.
2. Mix and apply resin to the prepared surface.
3. Mix and apply resin to laminate strip.
4. Apply strip to substrate while epoxy is wet.
5. Apply pressure to entire length of strip to insure full contact.

Fabric system:
1. Prime prepared surface (per manufacturers recommendations).
2. Saturate fabric and apply to the primed substrate. Or, apply resin to substrate and apply fabric into resin. Followed by a second resin application.
3. Apply multiple layers as required by specifications.
4. Apply protective top coat to system.

Near surface mounted systems:
1. Cut bars or strips to desired length and clean prior to the application
2. Saw cut required groove into concrete substrate and clean groove of any residual dirt or debris
3. Mix epoxy adhesive and partially fill the groove with epoxy
4. Install bar into groove
5. Fill any remaining portions of the groove with epoxy and clean any excess epoxy from around the groove

LIMITATIONS
1. Cold weather applications are limited.
2. Coatings must be applied in UV conditions.
3. Fire resistance of the systems is limited as are fire proofing options. Fireproofing may be required to be installed over the system
4. Supplemental reinforcing (not primary) system. Should be used only as secondary reinforcement.
5. Must be applied by experienced and qualified contractors.