Overview

The deterioration of reinforcing and prestressing steel within concrete is one of the prime causes of failure of concrete structures. In addition to being exposed to weather, concrete transportation structures in Florida are also commonly located in aggressive environments such as marine locations and inland water crossings where the water is acidic. Cracks in concrete create paths for the agents of the aggressive environments to reach the reinforcing and/or prestressing steel and begin the corrosive oxidation process. An innovative approach to combat this major issue is to replace traditional steel bar and strand reinforcement with Fiber Reinforced Polymer (FRP) reinforcing bars and strands. FRP reinforcing bars and strands are made from filaments or fibers held in a polymeric resin matrix binder. FRP reinforcing can be made from various types of fibers such as glass (GFRP) or carbon (CFRP). A surface treatment is typically provided that facilitates a bond between the reinforcing and the concrete.

Beneficial characteristics of FRP reinforcing include:
- It is highly resistant to chloride ion and chemical attack
- Its tensile strength is greater than that of steel yet it weighs only one quarter as much
- It is transparent to magnetic fields and radar frequencies
- GFRP has low electrical and thermal conductivity

Like any construction material, there are pros and cons to the use of FRP reinforcing:
- Due to its inelastic behavior and the emerging findings from ongoing research, current applicable design codes significantly reduce the allowable stress capacity that can be assumed when designing with FRP. Engineers must take into consideration the more stringent reduction factors in the applicable codes when designing with FRP reinforcing.
- Due to the manufacturing processes currently in use and the progressive standardization that they are undergoing, requirements for project specific acceptance testing of FRP can be more extensive compared to those which are required for steel reinforcing bars and strands.
- Storage and handling requirements for FRP reinforcing on the construction site can be more restrictive due to FRP's susceptibility to damage by overexposure to UV light, improper cutting or aggressive handling.
- The initial cost of the FRP reinforcing is considerably higher than traditional steel reinforcing. However, this higher initial cost may be partially offset by a reduction in the concrete cover and the elimination of corrosion inhibiting admixtures.
typically used for steel reinforced concrete construction in extremely aggressive environments. A longer service life of the concrete component may also be expected if FRP reinforcing is used by reducing the need for repairs and eliminating cathodic protection or sacrificial anodes.

Due diligence must be done to ensure FRP benefits outweigh the costs of implementation for each concrete component.

Traditionally, composite materials like FRP have been used extensively in aerospace and consumer sporting goods applications where the material's high strength to weight ratios were first exploited. In the 1960s US Government agencies recognized the potential benefits that composites can provide to society's infrastructure and thus begin funding significant amounts of research in the field of FRPs. Since then advances in the field of polymers, advancements in production techniques and implementation of authoritative design guidelines have resulted in a rapid increase in usage of FRP bars and strands, especially in the last 5 years. Because of these advances, the FDOT Structures Design Office has implemented its first specifications and design criteria to support the use of FRP bars and strands in major bridge components. The use of this innovative material in certain Florida bridge components will keep Florida on the leading edge in the design of state-of-the-art transportation facilities.

Usage Restrictions / Parameters

GFRP and/or CFRP reinforcing bars may be used in the following concrete components when approved by the SSDE:

- Approach Slabs
- Bridge Decks and Bridge Deck overlays
- Cast-in-Place Flat Slab Superstructures
- Pile Bent Caps not in direct contact with water
- Pier Columns and Caps not in direct contact with water
- Retaining Walls, Noise Walls, Perimeter Walls
- Pedestrian/Bicycle Railings
- Bulkheads and Bulkhead Copings with or without Pedestrian/Bicycle Railings
- MSE Wall Panels
- MSE Wall Copings with or without Pedestrian/Bicycle Railings
- Drainage Structures
- Concrete Sheet Piles

The use of GFRP and/or CFRP reinforcing bars in other locations will be considered on a case-by-case basis.

Developmental Design Standards for 24 inch square piles and concrete sheet piles with CFRP strands are available and can be used following the Developmental Design Standards Usage Process. CFRP strands may be used in other prestressed concrete piles when approved by the SSDE.

These usage restrictions take into consideration the following items:

- The criticality of the components and/or structures they are part of
- The desirable service life of these components and/or structures
- The historical in-service performance of these components and/or structures that were designed, detailed and constructed using the conventional reinforcing steel, prestressing steel and concretes that are currently required.

Design Criteria

See the following references for the application of FRP bars and strands for concrete reinforcement:

- "AASHTO LRFD Bridge Design Guide Specifications for GFRP-Reinforced Concrete Bridge Decks and Traffic Railings"
- ACI 440.1R-06 "Guide for the Design and Construction of Structural Concrete Reinforced with FRP Bars"
- ACI 440.4R-04 "Prestressing Concrete Structures with FRP Tendons"
- ACI 440.5-08 "Specification for Construction with Fiber-Reinforced Polymer Reinforcing Bars"
- ACI 440.6-08 "Specification for Carbon and Glass Fiber-Reinforced Polymer Bar Materials for Concrete Reinforcement"
- ACI 440R-07 "Report on Fiber-Reinforced Polymer (FRP) Reinforcement for Concrete Structures"
Additional design and detailing criteria are available in the 2015 FDOT Structures Manual, Volume 4 Fiber Reinforced Polymer Guidelines.

Specifications

Developmental Specifications and/or project specific specifications will be required for the use of FRP reinforcing.

Implementation Plan

The potential use of FRP reinforcing bars or strands for a given application will be evaluated on a project by project basis. Extensive coordination with the Structures Design Office will be required in order to develop acceptable final designs. See Structures Manual, Volume 4, Fiber Reinforced Polymer Guidelines for more information.

Developmental Specifications 400, 410, 415, 450, 932 and 933 are available on the Developmental Specifications webpage for the use of FRP reinforcing bars and strands. Additional Developmental Specifications for other concrete structural components will be written and made available on an as-needed basis.

Developmental Design Standard D21310 FRP Reinforcing Bar Bending Details and the associated Instructions for Developmental Design Standard D21310 are available on the Developmental Design Standards webpage. Development of additional Developmental Design Standards for Square Prestressed Concrete Piles, Precast Concrete Sheet Piles and Concrete Box Culverts is planned for the future.

FRP producers seeking to be included on the Approved Materials List may find guidance for material acceptance on the State Materials Office Fiber Reinforced Polymer Composites webpage.

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