Concrete Reinforcement and Fibre Reinforced Polymer

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Abstract: **The corrosion of steel reinforcement in concrete reduced the life of structures, causes high repair costs and can endanger the structural integrity of the structure itself. Fibre Reinforced Polymer (FRP) offers a number of advantages over steel especially when used in marine and other salt laden environments. FRP reinforcing bars are gradually finding wider acceptance as a replacement for conventional steel reinforcement as it offers number of advantages.**

Technical studies on a number of concrete structures from 5 to 8 years old and constructed with FRP reinforcement have shown that there is no degradation of FRP from the alkaline environment.

Keywords: Brief History, Manufacturing of FRP, Benefits, Difference with conventional steel bars, Resins, Design standards for FRP

I. INTRODUCTION

Reinforced concrete is a common building material for the construction of structures. While concrete has high compressive strength, it has limited tensile strength. To overcome these tensile limitations, reinforcing bars (rebar) are used in the tension side of concrete structures.

Steel rebars has historically been used as an effective and cost efficient concrete reinforcement. When not subjected to chloride ion attack, steel reinforcement can last for decades without exhibiting any visible signs of deterioration.

However, steel rebar is very susceptible to oxidation (rust) when exposed to chlorides. Examples of such exposure include coastal areas, salt contaminated aggregates used in the concrete mixture and sites where aggressive chemicals and ground conditions exist. In cold climates, treating snow with salt is another cause of accelerated deterioration of concrete bridge decks, when corrosion of steel rebar occurs, the resulting corrosion products have a volume 2 to 5 times larger than the original steel reinforcement. As the concrete cant physically sustain the high internal tensile stresses developed from this volume increase, it eventually may crack and spall causing further deterioration and loss of reinforcement properties ultimately requires potentially significant and high cost repairs and possibly the endangerment of the structure itself.

FRP bars are competitive reinforcing option in reinforced concrete members subjected to flexure and shear. FRP has compelling physical and mechanical properties, corrosion resistance and electromagnetic transparency. The rise of FRP reinforcement is particularly attractive for structures that operate in aggressive environments, such as in coastal regions, or for buildings that host Magnetic Resonance Imaging (MRI) units or other equipment sensitive to electromagnetic fields.

II. BRIEF HISTORY

Fibre Reinforced Polymers (FRP) have been used for decades in the aeronautical, aerospace, automotive and other fields. Their use in civil engineering works dates back to the 1950s when FRP bars were first investigated for structural use. However, it was not until the 1970s that FRP was finally considered for structural engineering applications and its superior performance over epoxy coated steel was recognized. The first applications of FRP were not successful due to its poor performance witin thermosetting resins cured at high moulding pressures. Since their early introduction, many new FRP materials have been developed with a range of different forms such as bars, fabrics, 2D grids, 3D grids or standard structural shapes. .

III. MANUFACTURING OF FRP

A manufacturing process called ‘Pultrusion’ is the most common technique used for the manufacturing continuous lengths of FRP bars that are of constant or nearly constant in profile. Continuous strands of reinforcing materials drawn from roving bobbins. A veil is introduced and they pass through a resin tank, where they are saturated with resins followed by a number wiper rings to remove excess resins. The strands are then led to a pre-former and then formed to their final shape and cured by a heating die. The speed of pulling through the die is pre-determined by the curing time needed. To ensure a good bond with concrete, the surface of the bars id usually coated with sand and then cut to length. The application of sand coating is an additional process, a layer of resin is applied (but not under heated conditions) and then the bar is coated with a thin layer of sand. Similar to steel reinforcement, FRP bars are produced in different diameters, depending on the manufacturing process. The surface of the rods can be spiral, straight, sanded-straight, sanded-braided and deformed. The bar to concrete bond is equal to or better than the bond with steel reinforcing bars.

IV. RESINS

A very important issue in the manufacture of composite s is the selection of the optimum matrix because the physical and thermal properties of the matrix significantly affect the final mechanical properties as well as the manufacturing process. In order to be able to exploit the full strength of the fibres, the matrix should be able to develop a higher ultimate strain tan the fibres.

There are two types of polymeric matrices commonly used for the FRP composites thermosetting and thermoplastics. Thermosetting polymers are used more often than thermoplastics. They are low molecular weight liquids with very low viscosity and with their molecules joined together by chemical cross links, hence, they form a rigid three dimensional structure that once set, can't be re-shaped by applying heat or pressure. Thermosetting polymers are polyesters, vinyl esters and epoxies. These materials have good thermal stability and undergo low creep and stress relaxation. The vinyl ester resin pre-dominantly cures during the pultrusion manufacturing process as the bar is drawn through the heated die. By the time the bar reaches room temperature, it is considered to be fully cured. Thermosetting polymers have relatively low strain to failure, resulting in low impact strength. Two major disadvantages are their short life and long manufacturing time.

V. DESIGN STANDARDS FOR FRP

The two main differences in designing reinforced concrete structures using FRP reinforcement are:

- FRP does not yield in a similar way as steel
- FRP bars have lower modulus of elasticity than steel. Furthermore, both codes do not allow for the use of FRP reinforcement in columns (due to insufficient research in that area)

VI. BENEFITS OF FRP

The benefits of FRP rebar are as follows:

- Corrosion resistance- when bonded in concrete, it does not react to salt, chemical products or alkali in concrete. As FRP is not manufactured from steel, it does not rust.
- Superior tensile strength- FRP rebar produced by the pultrusion process offers a tensile strength up to twice tat of normal structural steel (based on area).
- Thermal expansion- FRP rebar offers a level of thermal expansion comparable to that of concrete due to its 80% silica content.
- Electrical and magnetic neutrality- as FRP rebar does not contain any metal, it will not cause interference with strong magnetic fields or when operating sensitive electronic equipments & instruments.
- Thermal insulation- FRP rebar creates a thermal insulation within structures.
- Lightweight- FRP rebar is a quarter the weight of rebar of equivalent strength. It offers significant savings in transportation and installation.

Utilizing these inherent benefits, FRP rebar has a cost effective application as concrete reinforcing bars in the following markets on a life-cycle cost basis:

- Reinforced concrete exposed to corrosive environments- car parking structures, bridge decks, parapets, curbs, retaining walls, foundations, roads and slabs.
- Structures built in or close proximity to the sea water- quays, retaining walls, piers, jetties, boat ramps, caissons, decks, piles, bulkheads, floating structures, canals, roads and buildings, offshore platforms, swimming pools.
- Applications subjected to other corrosive agents- waste water treatment plants, petro-chemical plants, pulp/paper mills, liquid gas plants, pipeline/tanks for fossil fuel, cooling towers, chimneys, mining operations of various types, nuclear power plants.
- Applications requiring low electrical conductivity or electromagnetic neutrality- aluminium and copper smelting plants, manholes for electrical and telephone communication equipment, basis for transmission/telecommunication towers, airport control towers, MRI in hospitals, railroad crossing sites and special military structures.
- Mining/tunnelling/boring applications- temporary concrete structures, mining walls, underground rapid transit structures, rock anchors and wash down areas.
- Weight sensitive structures- concrete construction in areas of poor load bearing soil conditions, remote geographic locations, sensitive environmental areas, or active seismic sites posing special issues that necessitate the use of lightweight reinforcement.
- Thermal sensitive applications- apartment patio decks, thermally insulated concrete housing and basements, thermally heated floors and conditioning rooms.

VII. SUMMARY AND CONCLUSION

FRP has a very important role to play as reinforcement in concrete structures that will be exposed to harsh environmental conditions where traditional steel reinforcement could corrode. It is the unique physical properties of FRP that makes it suitable for applications where conventional steel would be unsuitable. Detailed laboratory studies of samples taken from reinforced concrete structures, aged from five to eight years old, have confirmed that FRP has performed extremely well when exposed to harsh field conditions.

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