Polymer Composites as Construction Materials

Application Summary Sheet 25

Title: Non-Ferrous Reinforcing Bars

Target Audience: Civil Engineers, Architects, Structure designers, Specifiers, Government Authorities, Construction Companies.

Keywords: Non-ferrous reinforcement, durability, FRP, GRP, design, reinforced concrete, rebars, case study structures, construction materials, reinforcing bars, composites.

Overview of application / summary:

In reinforced concrete structures exposed to aggressive environments, where chloride ingress or concrete carbonation can occur, the protection surrounding conventional steel reinforcement is overcome and corrosion can take place. This can lead to cracking and spalling of the concrete and eventually the structure may become unserviceable or unsafe.

The application of non-ferrous bars in place of steel can eliminate the susceptibility of the reinforcement to corrosion and subsequently lead to significantly longer service lives and lower maintenance requirements. Non-ferrous rebars are manufactured from polymer composite materials containing glass or carbon fibres embedded in a highly durable resin binder with a textured surface to achieve bonding to concrete.

Features of the product include high tensile strength (1000MPa) but lower modulus than conventional materials (45GPa). The bars are 25% the weight of steel; highly corrosion resistant to acids, chlorides and alkalis; non-magnetic; electrically and thermally insulating and may be machined with concrete cutting equipment.

Limitations include the inability to bend the product on site; no available coupling systems; longer transfer lengths; high partial safety factors currently applied; poor shear strength and low strain to failure.

Existing design codes (BS8110, 5400) have been adapted to provide guidance when applying FRP bars and these provide the versatility to significantly reduce the concrete cover layer since the concrete is not required to provide environmental protection to the reinforcement.

Costs for the bars are typically 3 times that of conventional reinforcement or 50% that of stainless steel bars however, given sufficient design freedom, overall project costs may be reduced when using these materials.

Impact of application

Engineering:

- FRP bars have a tensile modulus of up to 1000MPa but partial safety factors reduce the available design values significantly to 250-400MPa for glass and 500-600MPa for carbon products depending upon design life. These factors are due in the main to the effects of static fatigue (stress rupture). Stiffness for glass products is typically 35-45GPa and for carbon up to 150GPa. Bond strengths are between 10 – 18 MPa in 30 kN concrete.

- It is now generally accepted that quality manufacturers provide highly durable products, however, not all bars sold have been developed and tested adequately in the concrete environment therefore there is a danger of service problems if cost is cut at the purchasing stage.

- ASTM, Japanese, Canadian and UK design guidance is available for applying the materials.

- There is no requirement to provide concrete cover to protect the reinforcement and structural designs can be optimised accordingly. The design guidelines provide a framework for doing this. It should be noted that design from scratch specifically for FRP reinforcement is more likely to yield a cost effective solution than mere substitution of the reinforcement in a conventionally reinforced structure.

- Other performance features include, the bars are 25% the weight of steel; highly corrosion resistant to acids, chlorides and alkalis; non-magnetic; electrically and thermally insulating (except carbon products) and may be machined with conventional concrete cutting equipment.

- It is good practice to handle and store the materials with care on site and to seal all exposed cut edges before installation. Bars should be connected using plastic wire ties (not steel wires). It is not possible to site bend the materials currently but some manufacturers can provide bent products to order. This requires good and complete detailing of reinforcement cages.

- The products have been reported as easy to use and install on site.

Financial:

- Cost of FRP rebars is highly dependent upon quantity purchased. Typically prices per unit volume are 3-5 times greater than conventional black bar and between 50 -75% the cost of stainless steel based on UK steel prices. This results in an additional cost of about 4-8% for a typical highway bridge project. However, there are several other issues that need to be considered in a cost/benefit analysis, these include; the amount of bar required for reinforcing structures in view of the different mechanical properties; effect of redesign and reduction in concrete usage on whole component cost; reduction in weight of rebar and time saving during construction of cages; reduction in weight of section and subsequent reduced craneage and transportation costs. It has been estimated that typically a 15% weight saving in precast sections may be anticipated due to cover reduction although some case study analyses have indicated significantly higher savings are achievable (soil nail spreader plates from 200 – 47kg).

- From a through life perspective there is no reliance on the concrete quality, low permeability or membranes to protect the reinforcement and therefore the maintenance costs for this reinforcement are understood to be negligible.

- In the UK last year about 250 tonnes of non-ferrous reinforcement was specified. The UK market size is estimated as 15,000 tonnes, roughly a £50 million pa industry. In the USA, significant volumes have been reported, in excess of 5000 tonnes, and in Japan similar quantities have been recorded.

- The effect of the application of FRP bars will also significantly reduce maintenance and repair costs for UK structures (currently estimated at £500 million pa) potentially freeing up a significant portion of this money for new capital projects.

Environmental:

- There have been several conflicting studies relating to the comparison between producing steel and polymer composite products. Overall it is felt that these two materials have similar environmental effects with the exception that steel is more readily recycled at the end of life. However, the composite materials are designed to last longer and this advantage may therefore be challenged.

- When considering the application of FRP bars in concrete however, several specific advantages are evident; the potential reduction in concrete cover required results in lower utilisation of cement. Cement produces 20 times more CO_2 emissions during processing that steel or FRP bars. In addition, concrete structures containing steel reinforcement is difficult to recycle since the steel needs to be extracted prior to crushing. This is not the case with FRP bars. Lighter weight products also provides the opportunity to reduce emissions during transportation.

- Furthermore the visual environment is enhanced since there is no rust staining or concrete spalling associated with the use of FRP bars.

- The materials have no toxic or other fume emissions during use.

Social:

- As with all construction materials, it is good practice to use gloves, eye protection and a face mask when handling and cutting FRP bars. Workers on site have reported that the lightweight of the materials is an advantage during handling and cut edges are not sharp resulting in fewer hand injuries.

- Other social issues include; less anticipated disruption to daily life due to less requirements for maintenance on structures; less risk to motorists and pedestrians of injury from falling concrete.

- Current first cost purchasing policy within many construction firms is resulting in a slow uptake of this material not only in the UK but also across the world. Japan is leading the application of this technology with greater emphasis on through life costing in their purchasing decisions enabling widespread use of expensive carbon reinforced materials.

Robustness of research

Non-ferrous reinforcement has been the subject of comprehensive research over the last 10 years and supported by many case study and commercial applications.

The product is felt to be sustainable with 2 lead organisations promoting the product internationally and many local producers 'dabbling' with the technology.

The product is available in the UK as a home manufactured product or as an import from USA manufacturers. There are lead times of up to 12 weeks for orders and volumes are currently restricted to 3-400 tonne batches. However, sufficient demand will alter this situation.

Future developments

Significant R&D activity is ongoing in the areas of bond, fatigue, processing, materials, structural design, standardisation, site bending and durability.

Where to get further information

Companies

UK:
Eurocrete Ltd: eurocrete.trend@cwcom.net

USA:

Hughes Brothers Ltd: www.hughesbros.com
Dow Fulcrum Company: www.dow.com

Canada:

Pultrall Ltd: www.fiberglassrebar.com

Industry Association:
http://www.mdacomposites.org/Rebar_Mfg_Council.htm#RebarMfg

Design Guidelines:

UK:
Institution of Structural Engineers – Interim Guidance on the Design of Reinforced Concrete Structures using Fibre Composite Reinforcement.

USA:
ACI 440

Research

Confibrecrete Network: www.shef.ac.uk/~tmrnet/

FIB Task Group: allserv.rug.ac.be/~smatthys/fibTG9.3/