

Composite rebar 'ideal for Gulf'

GRP (glassfibre reinforced plastic) composite rebar is the next-generation material for concrete reinforcement in the region and with the recent acceptance of the material in the International Building Code (IBC), the construction industry can expect to see wider use of GRP in these applications.

In view of the soil conditions prevalent in the region, GRP rebar is the natural choice, given the numerous advantages offered by the material. GRP composite rebar offer corrosion resistance (impervious to the action of salt ions and alkalinity inherent in concrete) and are light in weight (approximately 25 per cent the weight of an equivalent steel bar).

As the rebar do not contain metal, they will not cause any interference in contact with strong magnetic fields or when operating sensitive electronic instruments. In other words, they are transparent to magnetic fields and radio frequencies. Further, the level of thermal expansion is comparable to concrete due to the high silica content (greater than 75 per cent) of GRP rebar. The GRP rebar are also electrically and thermally non-conductive. ASTM D7205 describes test methods for determining tensile modulus and strain properties of GRP rebar using American Concrete Institute (ACI) design guidelines.

The savings in construction and life-cycle costs with GRP rebar are multi-fold:

- Instead of low-permeability concrete with added corrosion inhibitors, conventional concrete can be used;
- Costs incurred in using expensive membranes can be eliminated;
- Reduced weight leads to lower installation time;
- Savings of at least 45 per cent in total cost of maintenance and demolition; and
- Savings of at least 15 to 20 per cent in the overall life-cycle cost.

The development of key codes and standards has catapulted the commercial acceptance of GRP rebar in the industrialised countries. And with GRP composites finally recognised by IBC, it can be considered a watershed in the global building and construction sector, including the region!

Standards & acceptance

North America is the acknowledged leader in the use of GRP rebar for concrete reinforcement. The concept initially mooted in the early 1990s paved the way for extensive trials and successful commercialisation towards the end of the millennium. The ACI and Japan Society for Civil Engineers (JSCE)

The case for manufacturing as well as use of GRP composite rebar in the Gulf region is very strong, given the region's resources and environmental conditions. S SUNDARAM* elaborates.



Composite rebar used at Nakheel's Palm Cove Canal in Dubai Waterfront, UAE.

have formulated design guidelines for the use of GRP rebar, while the Canadian Network of Centers of Excellence on Intelligent Sensing for Innovative Structures has published a design guide and manuals on the subject.

In April 2008, the American Composites Manufacturers' Association (ACMA) announced an effort to introduce GRP composites into the IBC – a model building code developed by the International Code Council (ICC) – to promote acceptance of composites in building and construction. The ICC final hearings were held in September 2008 wherein building officials “approved” as submitted, item FS196-07/08.

The new section of the 2009 IBC stipulates the proper use of GRP for building construction and will enable architects, specifiers and buyers to appreciate the benefits of GRP as a viable product. The code change provides recognition of GRP composites for many building applications and includes appropriate requirements to allow their use in a manner intended by the code alongside

traditional building materials.

Also in 2008, a team composed of ACMA members and the University of Miami successfully submitted new standards for the use of GRP rebar in concrete, to the ACI. After a rigorous process, ACI's Committee 440 adopted the new standards designed to provide fibre-reinforced polymer rebar manufacturers with critical tools to aid engineers in specifying composite rebar for structural applications. Coupled with the ACI design specification (ACI 440.2R-06), the standards enhance the use of GRP composite rebar and render it easier for manufacturers to produce them and have them qualified on potential jobs. The standards include:

- 440.5-08: specification for construction with fibre-reinforced polymer reinforcing bars;
- 440.5M-08: metric specification for construction with fibre-reinforced polymer reinforcing bars;
- 440.6-08: specification for glassfibre-reinforced polymer bar materials for concrete

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reinforcement; and

- 440.6M-08: metric specification for glassfibre-reinforced polymer bar materials for concrete reinforcement.

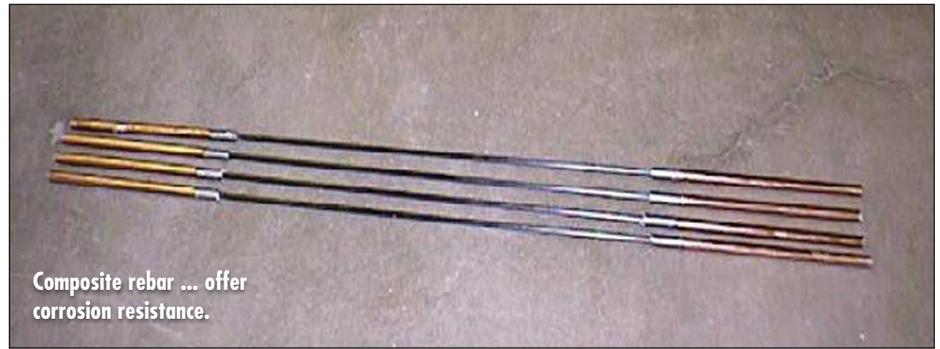
Concrete has high compressive strength but limited tensile strength. To overcome limitations in tensile, reinforcing bars are used in the tension side of concrete structures. Historically, steel rebar have been used as a cost-effective reinforcement. However, insufficient concrete cover, poor design or workmanship and the presence of large amounts of aggressive agents including environmental factors can lead to cracking of the concrete and corrosion of the steel rebar. While, steel rebar can last for decades without visible deterioration provided the concrete is not subject to chloride ion attack, they are prone to rust when exposed to chlorides especially in coastal areas, locations where salt-contaminated aggregates are used in the concrete mixture and sites with aggressive soil conditions. When corrosion occurs, the resulting products have a larger volume (two to five times) than the metal product from which they are originally derived. The concrete cannot sustain the tensile load developed from this volume increase and eventually cracks and spalls, leading to further deterioration of the steel.

The combination of ongoing deterioration and loss of reinforcement properties results in significant and expensive outlays for repair and maintenance, ultimately endangering the structure itself. A quick-fix cost-effective solution is the use of epoxy-coated steel rebar with stainless steel being a more expensive alternative.

Rebar using glassfibre in a resin matrix (generally vinyl ester or epoxy) provide superior tensile properties and built-in corrosion resistance and are also economically feasible from a life-cycle cost-benefit-analysis viewpoint.

The ACI 440 recommendations are based on principles of equilibrium and compatibility and the law of mixtures of the constituents (glassfibre and resin). The resin-glass interfacial bond characteristics are responsible for transferring the stress from concrete to the reinforcement and for developing the required stress in the reinforcement for an equilibrium, particularly when concrete cracks. Service limits in GRP reinforced concrete such as deflection, crack width and crack spacing are directly influenced by the bond properties of the reinforcement in concrete.

GRP rebar are anisotropic in nature with factors such as type and volume of fibre and



Composite rebar ... offer corrosion resistance.

resin, fibre orientation and quality control during manufacturing playing a major role in their mechanical characteristics. The new design philosophy adopted for GRP composite rebar allows consideration to be given to either composite rupture or concrete crushing as the mechanism that controls failure and is based on limit-state design principles, followed by checking for fatigue endurance, creep rupture endurance and serviceability criteria.

Applications

The following aspects have to be factored in when designing with GRP concrete rebar:

- Direct substitution of GRP rebar in concrete structures designed with steel rebar is generally not practical;
- GRP rebar have a lower modulus of elasticity and shear strength, thereby limiting applications to short spans of secondary structural elements; and
- GRP rebar applications are generally confined to reinforcement of concrete and not recommended to be used as a pre-stressing or post-tensioning element.

GRP rebar are produced by the pultrusion process and are specifically advantageous in concrete construction in areas of poor load-bearing soil conditions or active seismic sites that require lightweight reinforcement.

Due to the low modulus of elasticity, GRP rebar need to be supported at a spacing that is two-thirds that of steel rebar.

Other uses include tunnelling and boring applications requiring reinforcement of temporary concrete structures, typical examples being underground rapid transit structures, underground vertical shafts and mining walls. Specific examples of use in structures built in or close to seawater include quays, retaining walls, piers, jetties, piles, bulkheads and offshore platforms.

GRP in the region

The structural engineering division of the civil engineering department at the UAE University has done extensive research on the potential use of GRP rebar in the UAE

through Efors, the licensed consultancy with the university's research centre. The department is working on some ongoing projects in Reem Island and has been associated with other projects in Abu Dhabi, Fujairah, Ras Al Khaimah and Ajman in the past five years. GRP rebar have already been used in marine docks and waterfront structures such as Nakheel's Palm Cove Canal in Dubai Waterfront and in the Baker Hughes building in Dubai.

The UAE is already familiar with the use of GRP rebar and the Emirates Foundation is funding a research project on the performance of concrete structures using GRP rebar. What is required now is expanding the use of the composite rebar in numerous upcoming projects in the region.

In terms of manufacture, there are a few GRP processors in the region with pultrusion facilities, of which Pultron (Jebel Ali, Dubai) and Saudi Pultrusion Industry (Al Khobar, Saudi Arabia) merit specific mention.

Pultron commenced its manufacturing activities in the UAE earlier this year and will be relying on its 20-year expertise in producing quality GRP rebar at its main manufacturing facility in New Zealand.

The availability of the requisite types of glassfibre and resin (produced locally in the region) for rebar ensures that the region is self-reliant on raw materials and technology for mass production of GRP rebar. Further, in view of the region's prevalent soil conditions, GRP rebar is the natural choice and should be exploited to a greater extent.

The synergistic availability of materials, technology, design data and international standards makes a strong case for more extensive use of GRP rebar in construction activities in the region in the coming years, considering its immense potential.

** S Sundaram is a freelance writer with over 25 years experience in the global composites industry. He regularly contributes to several composites trade magazines in Europe, North America, Asia Pacific and the Middle East.*