S&P Global
Platts

METALS INSIGHT

Volume 11 / Issue 9 / May 5, 2016

GFRP rebars: composites building on a niche

Glass fiber reinforced polymer is gaining space over steel in some applications where corrosion-resistance is key. It won recognition when a fiberglass Disneyland attraction proved stronger than expected during demolition

Steel rebar customers are waking up to a new kid on the block. Fiber reinforced polymer rebar (FRP), and its most common variant, glass fiber reinforced polymer rebar (GFRP), are making small but steady inroads into the market for traditional epoxy steel rebar in the heavy construction industry where strength and corrosion-resistance are crucial, for instance bridge building. FRP rebars can also substitute stainless steel bars, galvanized and black bar steel.

GRFP rebars are so far "catching on" mainly in North America, which accounted for up to a third of the world's usage of an estimated $22 billion-worth of composite materials in 2015, according to industry specialist Sanjay Mazumdar, CEO of market research firm Lucintel. The region consumes around 80% of the world's GFRP rebars, according to Hughes Brothers, a leading producer.

In the absence of definitive market data, producers and analysts estimate the market for this niche product commands sales of anywhere between $20 million and $200 million annually, still a tiny sliver in a steel market currently estimated by independent consultant James F. King at around $600 billion annually. Rebars account for around a fifth of the steel market.

"Stainless or galv or epoxy rebar is already a very niche product in the vast carbon steel rebar market and GFRP may be a niche in a niche," says Paris-based consultant Marcel Genet, of Laplace Conseil.

As Sky Kurtz of Pultron Composites, a GFRP producer, says: "By no means will GFRP eliminate steel – in fact, around 95% of the time it doesn't make sense to use our product as it's costlier or the material properties don't make sense

(continued on page 2)

Bridge construction in the US using GFRP rebars. Photo courtesy of Hughes Bros.

EDITORIAL COMMENT

First developed in the 1930s and winning market acceptance for parts manufacture only in the 1960s, glass fiber reinforced polymer (GFRP) has from the 1990s gained ground in the building industry in the form of rebars, mainly in US and Middle Eastern markets. Its main advantage is resistance to corrosion, seen as steel's biggest enemy, and expected to become an even greater foe as global warming brings more climate change. A US user of GFRP, Texas-based Stromberg Architectural Products, reports that its architectural advantages were discovered with the attempted destruction of Disneyland's "House of the Future," built in 1956-7 entirely of fiberglass. "When the attraction was no longer deemed necessary, it was scheduled to be destroyed in 1967. Amazingly, the wrecking ball merely bounced off the structure, and the possibilities for GFRP were recognized and began to grow. By 1994, nearly 600 million pounds of composite materials were used in the building industry," Stromberg states.

The competitive properties of GFRP rebars, and the difficulties of disposing of or recycling them, mean the products face considerable opposition. They are direct competitors to stainless steel rebars, which may have a slightly shorter resistant life. A fierce debate is underway between the two camps.

GFRP producer Pultron Composites reports that Sydney North Side Storage Tunnel was designed to use stainless steel reinforcement, but lifespan was estimated at 60 years maximum in the harsh conditions. The design was changed to GFRP and expected lifespan rose to an estimated 100-125 years, it says.

Still, stainless does has the advantage of being 100% recyclable, as stainless producer Outokumpu points out. Pultron counters: "The cost and energy to remove any form of rebar from concrete is very high, and this may off-set any advantages of recycling. A more effective 'green' policy may be to ensure the embedded energy in the structure is 'accounted for' over as long a period as possible by making the structure last as long as possible." Platts Metals Insight attempts to uncover some of the pros and cons of the upcoming product. — *Diana Kinch*

GFRP rebars: composites building on a niche

...from page 1

(e.g. lower modulus). However, in around 5% of applications, at a small upfront cost premium (system cost) to steel, you can double or triple the life of a concrete structure and/ or solve other challenges associated with steel (e.g. induction of current, needs for temporary/ cuttable reinforcement)."

The market is so far small but has potential, King says. GFRP rebar is a high-value added product and Hughes Bros puts its own sales growth rates at 20% a year or higher. Governments, the main infrastructure providers, are discovering that it is more cost-effective to use a composite product that will significantly extend the life of public structures where corrosion was previously a weak point. The Ministry of Transportation of Ontario, Canada, a leader in the use of GFRP in bridges in North America, has stopped using epoxy coated rebars in government-funded transportation projects and says it continues to use stainless steel "with discretion."

The Oregon Ministry of Transport has recommended against using epoxy-coated rebars in coastal applications while studies in the states of Virginia and Florida have alerted to rapid deterioration of these products.

Corrosion: a high cost

According to NACE International, the US-based Corrosion Society, corrosion has an estimated direct cost to the US economy of $138 billion annually. In the water supply and sewage industry, an estimated 50% of all operational and maintenance costs and 90% of lost water is corrosion-related, says the society, whose preventive strategies include changing the misconception that nothing can be done about corrosion and changing policies, regulations, standards, and management practices to increase corrosion savings.

With corrosion becoming a more serious issue due to global warming, the advantages of FRP products are plain: producer BP Composites states that GFRP rebars maintain corrosion resistance for 100 + years, compared to 75 years for stainless, 40 years for galvanized and 30 years for epoxy-coated steel rebars. GFRP products are ¼ the weight of steel and with twice the tensile strength; non-magnetic and electrically and thermally non-conductive. They are impervious to chloride ion and chemical

WHAT IS... GALVANIZING?

This is the application of a thin layer of zinc or zinc-aluminium alloy to steel to provide corrosion resistance. The two principal coating methods are continuous galvanizing and batch (or general) galvanizing.

Continuous galvanizing is used to coat flat-rolled steel (mostly cold reduced, but some hot rolled), and also wire and tube. Zinc is applied either by hot-dip coating (the steel passes through a pot of molten zinc) or electrolytic coating (deposition takes place in a series of electrolytic cells). Hot dip is the most common method as it is cheaper.

The key stages on a continuous hot-dip line for strip are pre-cleaning, heating, coating, air-knife (to control coating thickness), cooling and re-coiling. An electrolytic line has no heating or cooling stages.

Continuous lines operate with an endless steel strip created by welding the end of one coil to the start of the next. This highly productive coating process can typically throughput 200,000-500,000 tonnes/year of coil.

Batch galvanizing is the coating of individual finished items or components (typically street furniture) by dipping them in a large bath of molten zinc.

S&P Global
Platts

METALS INSIGHT

Volume 11 / Issue 9 / May 5, 2016

ISSN: 2058-749X

Metals Insight is published fortnightly by Platts, a division of S&P Global, registered office: 20 Canada Square, Canary Wharf, London, UK, E14 5LH.

Officers of the Corporation: Harold McGraw III, Chairman; Doug Peterson, President and Chief Executive Officer; David Goldenberg, Acting General Counsel; Jack F. Callahan Jr., Executive Vice President and Chief Financial Officer; Elizabeth O'Melia, Senior Vice President, Treasury Operations.

attack and dramatically reduce breaking and cracking of concrete exposed cyclic loads, the producer says.

According to the University of Miami FRP products can be molded into any shape and can be preassembled.

Students at University of Miami replace steel with GFRP on bridge research project. Photo: Composites Manufacturing; University of Miami

Market growth

Jasper Holdsworth, managing director of Pultron Composites, expects the market for premium reinforcement products, including FRP, to grow to take 5% of the reinforcement market by 2030.

"The market is broken down into regular steel reinforcement (97%) and premium products reinforcement (3%) mainly used to combat corrosion," Holdsworth said. "Premium reinforcements mean stainless steel rebar, galvanized steel rebar, epoxy coated steel rebar and other rebar (including FRP rebar). The trends are that the premium products segment is growing into the regular steel market and is expected to grow to 5% of the rebar market within the next 15 years, and within the premium products segment, that FRP rebar is growing at a pace of about 15-20% p.a. So there are two positive forces at play. We think FRP rebar will capture a niche share of the steel market: however capturing a small niche based on the figures above would mean a penetration rate of only 0.25% of regular steel – but the total addressable market in 2030 if only 25/10,000 reinforcing bars and wire rods were FRP rebar could be in the US$ billions p.a. "

Stainless: fighting the same battle

Manufacturers of stainless steel rebars and some steel coated products recognize the challenge posed by corrosion, which may be steel's main natural enemy. "Premature deterioration of reinforced concrete structures has become a serious problem worldwide due to corrosion of the embedded steel," says the International Stainless Steel Forum on its stainless steel rebars website. "The estimated annual cost of corrosion in the USA for bridges alones exceeds US$8 billion. The structures chiefly affected are those situated in aggressive environments such as marine and road bridges to which de-icing salts are applied during winter periods."

The competition between products is a sensitive issue, and the steel camp claims design and recycling advantages.

Leading stainless steel producer Outokumpu does not see fiber-reinforced polymers as a threat but as a material that has excellent but limited use in its own niche.

"Stainless steel has clear benefits compared to fiber-reinforced polymers, which cannot be used in all applications. In construction, FRPs are used in repair projects, where for example the concrete needs to be strengthened afterwards: there FRP's initial cost is lower (taking into account demolishing of the old concrete cover and down-time cost of the application). However, in new construction projects it is not often the first choice due to its high price, while the cost of stainless steel is a little less, and its life-cycle costs low. Compared to FRP, stainless steel has better fire resistance and it can be bent: FRP cannot be bent, and epoxy, which is used in its installation, is not fire resistant – neither are its properties over time or resistance to water and temperature not yet fully known," the stainless steel producer says.

Stainless steel is also easy to install, maintenance is not required and its life cycle is much longer, argues Outokumpu. "Stainless steel makes concrete work better: it allows thinner cover, prevents concrete from cracking due to corrosion and sustains even deficiencies of concrete (such as insufficient cover and poor quality or compaction). At the end of its life cycle, stainless steel can be 100% recycled unlike FRP, which needs to be disposed."

Other sources note that stainless steel is corrosion resistant throughout its mass. Thus, if its surface is cut, scratched or otherwise damaged in the manufacturing, transport or erection processes, the underlying material retains its stainless qualities. On the contrary, coated materials place their coating at risk if the material is bent beyond the stretch limits of the coating or if the material is scratched through the surface of the coating. In either case, the underlying metal then becomes vulnerable.

Countering some of these arguments, FRP producers claim that technology has been developed to bend FRP products and indeed, that all major GFRP rebar suppliers offer bent rebars in a wide variety of shapes. FRP can work out at a lower price than stainless in some applications and does not rely on a protective coating, being corrosion-resistant throughout its cross-section, the FRP camp says.

FRP rebar properties

The composite material is gaining a track record. First produced in the 1960s, FRP rebar gained commercial ground in the 1980s in Japan where it was used in high speed trains and started to be adopted in the early 1990s in the US power transmission industry, in the late 1990s being adopted in Canada and the US for structural applications, now its main usage. As well as being attractive for internal reinforcement for concrete structures requiring corrosion

resistance, they are suitable for use in environments involving electromagnetism. They are particularly suitable for:

- Structures built near seawater, for instance quays and canals;
- Structures near or touching corrosive agents, for instance de-icing salts;
- In sites with wastewater treatment, petrochemicals, liquid gas plants, mining walls, underground transit systems, aluminum and copper smelters, electrical and communication equipment, magnetic resonance imaging installations;
- Constructions in poor load-bearing soil conditions, in thermally-sensitive applications, industrial refrigeration units, nuclear power and dump sites or active seismic sites.

"After evaluating the performance of bars that have been in service for 15 or more years we are extracting the bars, measuring their properties where possible, looking at them with scanning electron microscopes (SEM) and energy dispersive X-ray spectroscopy (EDS) to look for chemical traces that would indicate signs of GFRP bars degrading and finding none," said Doug Gremel, non-metallic reinforcing director of US-based Hughes Bros, a GFRP producer since 1993. The company was initially stimulated to begin exploring GFRP rebar after Tennessee Valley Authority engineers wondered if Hughes' insulator core bars could be used as rebar to mitigate electromagnetic transparency in transformer pads, Gremel said.

Who manufactures and distributes?

Hughes Bros, which produces under the Aslan trademark, says it has 57% of the North American market and sees market growth of 20% annually in the GFRP rebars market, not including other FRP products including rockbolts for coal mining and tunneling. Nucor subsidiary Harris Rebar, a leading fabricator, installer and distributor of concrete reinforcing steel and related products, has reportedly teamed up with a GFRP rebar producer on a distribution venture. Other producers include Pultron Composites, producer of the trade-marked Mateenbar; Mateen Corporation, an operating subsidiary of Pultron based in Dubai, UAE; Fiberline Composites, which produces ComBAR; Pultrall Composites; Firep; BP Composites and Marshall Composites.

Following Harris Rebar's reported link up with a GFRP rebar producer, other link-ups to facilitate distribution may occur. "We are in active discussions with key rebar industry players in Canada and Germany," Pultron Composites said last month.

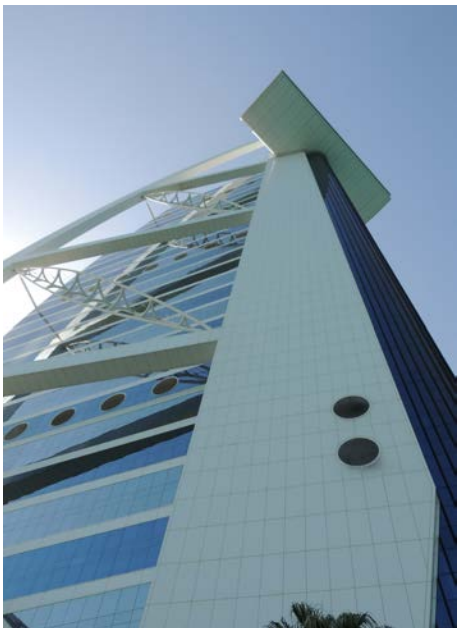
Competitor-producers are reportedly emerging in China and Russia. "In the long-term China will be a big market: but none of us are willing to give our technology," says Pultron's Kurtz.

Research continues

Research has been painstaking and time-consuming, including by end-users such as the Ministry of Transportation of Ontario.

"The research at MTO started in the mid 1990's and it was not until 2006 that the Canadian Highway Bridge Design Code allowed the use of GFRP as primary reinforcement in bridges. The technology is still evolving and new products are being developed on an ongoing basis," said David Lai, Head, Rehabilitation Section, Bridge Office at the Ministry.

MTO built the first bridge deck with FRP reinforcement in 1996. "FRP reinforcement can be either glass fibre or carbon fibre, both are non-corroding in a chloride environment," said Lai. "Due to the winter condition in Ontario, de-icing salt is used extensively on highways and it causes corrosion of black steel and associated concrete damage, even epoxy coated reinforcing bars have not performed



GFRP products were used in the construction of Dubai's Burj Al Arab Hotel. These included SHED wave energy dispersion units, made with white concrete, with octagonal and circular layers of mateenbar reinforcement. Photos courtesy of Pultron Composites.

satisfactorily. FRP is therefore adopted as a premium reinforcing material for enhanced durability." The product is being used for internal reinforcement for bridge decks, barrier walls, precast box girders, closure strips for precast decks replacing black steel and epoxy coated rebars in these applications, he said.

As a research project, the University of Miami is building "The Innovation Bridge" a 70-foot long GFRP bridge within the university campus, using no steel. "No steel means no corrosion" says its promotional video. The University is also partnering with the Florida Department of Transport to build a vehicular bridge near Tampa.

Geographic spread

North America's harsh winters make it the ideal environment for use of GFRP. The products "would have a limited geographic market initially," believes James.F.King. "Still, if they catch on volumes will go up and costs will come down," he said, noting that today there are more construction projects in warm climates.

Pultron's Mateenbar has seen good growth in its Middle East market driven by infrastructure investment and expects continuing steady growth in the region even with current oil prices. Rob Fordyce, general manager of Pultron's Middle East facility, says the company has been active in the "highly corrosive" saline soil environment of the Gulf Cooperation Council region for 16 years and started manufacturing in the region six years ago, supplying to the new metro system that Qatar is building for the 2022 World Cup and projects including Dubai's landmark Burj Al Arab Hotel. Pultron is also hopeful it will gain new contracts in Fiji, where it is talking to the government, which has "massive corrosion problems which consume 20% of its budget", on provision of 100% of its transport infrastructure, reports Kurtz. At the same time the company has a three-year strategic plan to deepen its reach into the fast-growing, larger North American and Western European markets.

Hughes Bros says that while the US is the main consumer, Middle East, South America and Europe are also consumers, with Asia lagging a little behind.

Standards: still being developed

The lack of product standardization in some areas of composite raw materials meanwhile hinders widespread use of GFRP and sister product Carbon Fiber Reinforced Polymer (CFRP), according to Lucintel's Mazumdar, writing in Composites Manufacturing Magazine in January. CFRP, considerably pricier than GFRP, is used primarily where product weight and strength are both of critical importance, for instance in BMW electric cars, aircraft and wind turbine blades.

Standards for the usage of FRP are not uniform worldwide. Standards were adopted in the US as long as 23 years ago and also exist in Canada, Japan and Norway. However, they are still being drawn up in the European Union and in Asia, which may account for the product's relatively low usage in those regions, producers say.

Higher upfront costs

The Ministry of Transportation of Ontario says the initial cost of the composite product works out about 30% higher than an equivalent design with epoxy coated rebars, but the life cycle cost is lower. MTO is probably spending about C$3 million annually on GFRP rebars, Lai said.

Compared with black steel rebars (which are less expensive than epoxy-coated rebars), GFRP works out 1.6 to 3 times more expensive as an upfront cost, producers say. "GFRP may add 5% to the cost of a project, but we can look at this as a kind of insurance policy," said Pultron's Fordyce. Compared to use of Grade 316 maritime grade stainless steel, meanwhile, GFRP would work out 60% cheaper, he says.

BP Composites says that, depending on volume, a #3 10 mm plain black steel Grade 40 rebar can be 1/3 the cost of a #3 10mm fiberglass rebar. As the diameter of the bars increase this gap narrows to a point where a #8 22 mm plain black steel bar is only slightly less expensive than #8 22 mm fiberglass rebar. In some applications less concrete cover and reduced water proofing costs result in lower initial cost for a project using FRP, it says on its website.

Using a high price for GFRP and very low price for black steel rebar, the cost to build a 20 ft. x 20 ft. garage pad with black steel versus GFRP would be $4,000-$6,000 for a Grade 40 Black Steel Concrete deck and $4,400-$6,400 for a GFRP reinforced concrete deck, BP Composites says.

"Many life cycle costs studies comparing black steel to GFRP have been completed," BP Composites continues. "They consistently conclude that the cost to protect, preserve and repair black steel in concrete is very high. So high, in fact, that even free black steel rebar still has a higher installed cost than GFRP in some applications," it says.

Design challenges

Both GFRP rebar producers and independent analysts are conscious of design challenges with the composite material.

"There seem to be some serious design and construction limitations with GFRP rebar; steel is much more flexible to use on-site," says independent consultant Roger Emmott of Roger Emmott Associates Limited. "I think the material must be taken seriously but surely is unlikely to gain share rapidly."

BP Composites warns that since the mechanical properties of GFRP fiberglass rebar differ from those of steel, design engineers should consider recommendations made in published design and construction guides prior to using GFRP fiberglass rebar in their structures.

"Direct substitution of GFRP fiberglass rebar with steel rebar may not be possible in some cases," the producer says. "A lower modulus of elasticity and shear strength may impact the number of reinforcing bars required. GFRP fiberglass rebar has a limited maximum sustained shear stress. Guaranteed design tensile strength of fiberglass rebar has to be de-rated in certain applications. Some types of GFRP fiberglass rebar are not suitable for certain pre-stressing or post-tensioning applications."

More growth to come?

According to MTO's Lai, demand for GFRP rebars can be expected to grow further.

"MTO has taken the lead to adopt GFRP reinforcement as an alternative material for durability; other Canadian provinces may

follow in the future in which case the market will grow. The US has a lot of deteriorated bridges that could use this material as well in the future," Lai said. "New bridges are required to have a design life of 75 years by code, GFRP can meet this requirement. Since there is a backlog of deteriorated structure that needs to be replaced in North America, there will be the demand for corrosion resistant reinforcement for quite some time."

The fight by GFRP rebar producers to gain market share and recognition continues. "The novelty is high but awareness is (still) low," says' Hughes Bros' Gremel. "It's been a very slow and painful adaption period but we're gaining more acceptance and we're constantly busy." — *Diana Kinch*