CARBON FIBRE COMPOSITE REINFORCEMENT

A Safety Belt for Structures and New Possibility to Light Constructions

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A Safety Belt for Structures and New Possibility to Light Constructions

During recent years news of collapsed roofs have taken the Finns by surprise. In exceptional circumstances the structures' load capacity has been exceeded. Carbon fibre composite reinforcement is a method with which basic structures can be reinforced almost unnoticed, without adding notably to the structures' weight. Carbon fibre reinforcement can be applied to various structures and materials.

Carbon fibre composite plates and bars are used for the reinforcement of structures. Using special adhesives, they are attached to plane surfaces in plates and bands. Compared to a steel reinforcement the increase in weight is nonexistent.

A pioneer in Finland TEKE has started to apply carbon fibre composites to reinforce structures. TEKE is part of the European co-operation network, which represents the British Exchem's long-term know-how in the field. Besides application know-how e.g. from Exchem offers TEKE the reinforcement materials as well as the necessary special adhesives to attach them to surfaces of concrete and other materials.

"For several years already carbon fibre composite reinforcements have been our daily work. We have learned much about various applications all around Europe. I myself have controlled tens of applications from Dubai to China. Several of them have been such that it wouldn't have been possible to do the job using any other technology. The variety of requirements has been very extensive. It has been necessary to add floors to an old building and to build a parking lot on the roof. A railway bridge has been rebuilt to carry heavy ore transports. In many cases the use of supporting structures made of steel would have been architecturally impossible, and the transfer and attachment of long steel bars would have been overwhelmingly expensive and inconvenient", Steve J. Richards from Exchem says.

"Thanks to this co-operation we've had 'a flying start' in making use of the new technology in Finland. This field calls for experience. Without it it would take years to study all that is needed", says Esa Moilanen, TEKE's CEO.

The basic benefits of carbon fibre composite are to a great extent the same as those of other composite technologies: lightness as well as good corrosion and temperature resistance. There are various shapes of carbon fibre composite reinforcements: plates, bars, bands and textures. When plates and bands, they are attached to the plane surfaces using special epoxies. Buttresses are reinforced with elastic texture that is fixed around the buttress. This hinders the thin buttresses from buckling (? nurjahtaminen), and also the structure's popping up (? pullahtaminen) even in thick buttresses. Normally the coal fibre reinforcement is embedded and fixed to a furrow milled into the structure.

Steve J. Richard, Exchem and Esa Moilanen, TEKE examinig reinforcement alternatives for a bridge of concrete.

Buttresses are reinforced by wrapping and fixing carbon fibre composite texture around them. It hinders the buttress from breaking trough buckling and popping

I believe that carbon fibre reinforcement will very soon become more common both in reparations, renovations and new applications. It is easier to carry out lighter architecture using composite reinforcement because a thin carbon fibre composite bar is able to carry heavier loads than a thick buttress made of some other material. In In addition, the structure's total weight will be lower. However, one must be aware of the security risks and know thoroughly how to make correctly use of the new technology", says Richards.

"We have many decades' experience of structures made of concrete as such, of repairing and coating them, and protecting them against wear, chemicals and moisture. We have had it easy to adopt this new reinforcement method. We were already familiar with the basic work. Without long-term, deep basic know-how the repairers and reinforcers of structures of concrete take very big risks. Anybody can make a nice surface but only a few can make a lasting whole. In my opinion there is a great demand for the coal fibre composite reinforcement method both in renovation and new structures. TEKE will lead the way", assures Moilanen.

"I have reinforced bridges, arches, roofs and floors as well as foundations for the construction of additional storeys all over the world. Carbon fibre composite reinforcement has often been the only viable alternative", says Steve J. Richards.

"Carbon fibre composite reinforcement of already existing structures increases the safe load and security margin, and enables light-looking architecture", says Esa Moilanen

TEKE has chosen one of Finland's leading structure reinforcement firms, Suomen Rakennusvahvistus Oy, to be one of its installation partner. *Working all together we can offer comprehensive know-how in the field of repair and reinforcement of structures as well as technologies. With combined resources we can carry out even large projects efficiently and quite creditably", Moilanen continues. This cooperation promotes further the know-how in the field of repair and reinforcement of structures and enables a fast and good-quality carrying out of even extensive projects. Applications for carbon fibre composite reinforcements can be found in construction, infrastructure, vehicles and mechanical engineering, i.e. wherever material with overwhelming strength compared with its gravity is needed. Several universities have started to research this field in depth. There are already books with calculation schemes available to assist the planning. Also tolerance tests are carried through on a full scale. Yet there is still much to learn about composite reinforcements also in the future.

Carbon fibre reinforcements. They can be delivered cut-to-size or in reels.

What Carbon Fibre Is and Why Is It So Firm?

It does not bend although you would wring it with your knuckles white. The lengthwise carbon fibres in a 100-gram carbon fibre composite bar do not agree to stretch nor be pressed.

Carbon has many states of aggregation, among others soft graphite and the world's hardest material, diamond, where each atom is tightly linked with four surrounding atoms. Carbon fibre is carbon. Owing to carbon's hexagonal crystalline structure carbon fibre's carbon molecules are attached to each other with strong covalent bonding during the manufacturing process, thus forming solid atomic levels.

Manufacturing Carbon Fibre

Today the bulk of carbon fibre is manufactured of PAN fibre (polyacrylnitrile) or rayon fibre. Manufacturing carbon fibre of PAN fibre is a continuous process where the white initial fibre is oxidized through heating at approx. 300°C. This phase directs and binds the molecules. In the second phase the fibre is carbonized in a space that is free from oxygen first at approx. 600°C, and after that at approx. 1500°C. During this process typical bands emerge in the fibre and the density and firmness of the fibre increase. The fibre has become almost pure carbon, with less than 1% impurities. It is now fit for commercial use. The firmness of the fibre can be further increased through graphitizing so that the stretched fibre is heated in a space free from oxygen to approx. 1500°C. Through regulation of the temperature it is possible to produce either very firm or stiff fiber. Finally, the fibre is coated in order to improve the adherence of the fibre and binding agent used, and its handling properties in the final use.

Through EXEL Pultrusion Carbon Fibre Composites Firmer Than Steel for the Use of Industry

In 1879 Thomas Alva Edison heated cotton and bamboo fibres turning carbonized fibre into a filament of bulb. Quite soon wolfram proved better than carbon filament in bulbs, but towards the end of the 1950s a new area emerged for the use of the old idea. Carbonizing and processing various fibres in the market they could be made harder than steel, thus starting the production of carbon fibre composites. At the same time also the production of glass fibre composites was initiated. The use of carbon fibres emerged almost exclusively from the needs of aviation industry. Today whoever can have carbon fibre in his/her hands, for example as the shaft of a golf club.

EXEL's activities are divided into industrial business (sample in the hand) and sports business (samples in the background), says Jari Sopanen

Sporting people can possess Excel carbon fibre skiing or walking sticks. From a landing airplane many of us have seen yellow approach light masts manufactured by Exel. We may have continued our journey in an airfield bus or train, the components of whose body have been manufactured by the same enterprise. Common to all these examples is that they have been made of light and hard-wearing composites. Finnish Exel Oyj is the world's leading deliverer of composite profiles.

What Are the Composites?

In accordance with its name, a composite consists of more than one material, i.e. reinforced fibre and binding agent. The reinforcing material (lujite) is usually carbon or glass fibre. Other materials used are among others FIBER-LIKE aramide, silicon carbide, and boron. E.g. epox, vinyl ester, or polyester are used as binding agent. Fibre gives firmness to the composite, the binding agent binds the fibres tightly together, apportions the load in the fibre layers and gives an object the form needed. Characteristic of composite structures is, especially, that their stiffness and firmness in relation to their weigh is very great, and in carbon fibre composites in a class of its own. In a composite the fibres can be parallel or multi-direction reinforcements. Composites are used in very different industrial applications, for instance machine parts, the bodies of airplanes and other vehicles, sports equipment, the vanes of wind power plants, pressure chambers, helmets, as anchor lines and structure enforcements. Compared with metal structures, composites are superior wherever lightness, great firmness and stiffness as well as the smallest possible coefficient of thermal expansion are needed.

Carbon Fibre Composites

The weight of carbon fibre composite is only one fifth of the weight of steel. The quality of carbon fibre used defines the composite's firmness. Commercial carbon fibres are divided into three categories on the basis of their firmness: HS, HM and UHM, of which UHM is three times as stiff as steel. Carbon fibre composites maintain their stiffness and firmness in temperatures from absolute zero point to some two hundred degrees, and their strain is especially small under load. Owing to their minimal thermal expansion they are suitable for use in places where calibrations and action gap must keep in various temperatures and loading situations. In demanding circumstances composite is a competitive alternative when reinforcing concrete. The unique corrosion resistance, endurance limit, high natural density - which enables high rotation speeds - as well as ability to damp oscillation, and thermal insulation qualities make possible structures with essentially better performance values than those of metals.

A miniature glass fibre composite top of a lightly constructed airport approach pole. In case of crash a full-size pole goes safely into pieces.

Machines made of carbon fibre composite are faster and they consume less power, because the own masses of moving machine parts are only a fraction compared with those made of metal. In rotating rollers and other fast moving machine parts vibration problems diminish essentially when the rotating mass is small. When the own mass remains small in beam constructions the span (jänneväli) can be longer. Replacing offshore anchor chains made of metal with lines made of carbon fibre composite makes it possible to expand the range of use (käyttöälue) to new depths thanks to small gravity.

Glass Fibre Composites

In several applications carbon fibre is an unnecessarily firm and expensive material for the products concerned. Then glass fibre or, alternately, other fibres are used as reinforcement. Adding colour to the binding agent gives the final product the wanted colour. In general, glass fibre composites are suited for rods and casings (varsiin ja koreihn) that ought to be light and stiff, e.g internal and external coachwork panels of cars and trains as well as trailer components. As laminates the composites are suited e.g. for construction and furniture production. In the vicinity of runways, light lattice masts that break safely in vase of crashes are examples of the use of glass fibre composites.

What Is Pultrusion?

Pultrusion is a production method of composite composite profiles where bunches of reinforced fibres that have been dipped into the binding agent are pulled through a mould with a wished profile. The result of this continuous process is ready profile in a wanted shape. When ready, the profile can be either a bar or pipe or even a polymorphous structure with many hollows. The reinforced fibre and binding agent used define the properties of the final product. The world market of pullthroughsion is expanding rapidly. It is mostly a question of finding new industrial applications and increase in production resources. There are a few dozen significant actors in the world market of pultrusion.

Exel, the Leader in Pullthroughsion

The Finnish Exel Oyj, established in 1960, is the world's biggest manufacturer of products made using the pullthroughsion technique. Exel uses self-developed production methods. It has 11 production plants, in Finland at Mäntyharju and Kiihtelysvaara. In the Olympics of the 70s composite skiing sticks manufactured by Exel made a major breakthrough. The firm continues to produce high-class skiing and walking sticks to the world market.

"Our activities are divided into industrial business and sports business. An OEM manufacturer we produce e.g. composite masts. Future's biggest potential lies in the industry's new solutions", says Mr. Jari Sopanen, Sales Manager for Exel Oyj's industrial products.

"There are still many unexplored applications for composite. We tailor solutions and help our customers to utilize composites when they tell us about their needs. 95 % of the products in our industrial business are tailored for the customer. Using correctly selected materials and production methods it is possible to offer technically suitable and competitive solutions. Thus, our slogan is "Reinforcing Your Business", says Sopanen.

Successful application of composite technology is the sum of three factors. What is needed is the knowledge of reinforced fibres, binding agents and production technology.

"When it comes to pullthroughsion technology we are the leaders in the world. Other production methods we are using are pull-winding, co-winding and continuous lamination. In the pull-winding method fibres are reeled also cross-wisely in addition to length-wise fibres. In the co-winding method it is possible to manufacture products with pull-winding properties but also products whose cross-section changes, such as e.g. skiing sticks. Continuous lamination enables the production of thin composite laminates with over one meter in breadth", says Sopanen.

Branches making use of composite technology in the future are e.g. transport equipment industry , infra-structure, wind-power, offshore, consumer products and construction. On the other hand, several applications have not found a suitable composite as yet.

"There are still many unexplored applications for composite. We tailor solutions and help our customers to utilize composites when they tell us about their needs. 95 % of the products in our industrial business are tailored for the customer. Using correctly selected materials and production methods it is possible to offer technically suitable and competitive solutions. Thus, our slogan is "Reinforcing Your Business", says Sopanen.

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