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New Structural Material - Fiber Reinforced Plastics

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Civil - Composite Materials & Technologies

New Structural Material - Fiber Reinforced Plastics

The Need

Traditional structural materials are heavy and require a great deal of maintenance. If a new breed of structural material could be produced that was lighter, stronger and more resistant to corrosion, impacts, parasites and chemicals, it could be a good substitute for steel, concrete, masonry and wood.

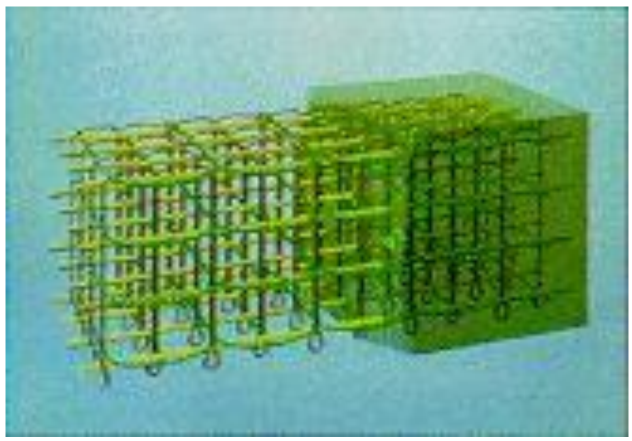

Figure 1Carbon 3-D Fabric, developed by Kajima (above), was used in the curtain-wall panels of the Sea Fort Square building in Japan's demanding coastal environment.

The Technology

One new material that has the potential to meet these demands is starting to show up on the construction industry market, it is Fiber Reinforced Plastics (FRP). Some technologies that have been developed using FRP materials within the last few years are listed as the following:

Structural Shapes

FRP can be made into constant cross-section structural shapes, such as W-sections and tube sections, through the pultrusion process of manufacturing. Almost any shape, or combination of shapes, can be created with the pultrusion process. Pultruded structural shapes have good strength characteristics, are very light, require little or no maintenance, and can be erected easily and quickly.

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Concrete Reinforcing

FRP has all of the major requirements to provide adequate tensile and compression reinforcing in concrete structures, but eliminates many of the poor qualities of standard steel. It can be used in applications requiring reinforcing in one, two, or three dimensions, although pultrusion can only be used to create one-dimensional reinforcing. The other types of configurations are developed by weaving mats of fibers, impregnating them with resin, and then curing the resin.

Prestressing and Post-Tensioning Tendons

Generally, concrete has been prestressed and post-tensioned with high-strength steel cables to help it resist tensile stresses, reduce cracking and deflections. However, FRP has many characteristics that make it a better candidate for the tendons in concrete structures compared to steel, including high tensile strength, flexibility with regard to size and shape, light weight, and corrosion resistance. Especially, since FRP does not suffer any adverse affects from exposure to environmental factors, the post-tensioning can be greatly simplified by allowing the cables to reside outside of the structure itself. With this change, the concrete will not have to accommodate post-tensioning ducts thus reducing concrete fabrication time, and the process of installing the cables is much simpler. Some characteristics that may make it a poor candidate for this application are not fully understood, but could include low modulus of elasticity, creep, and fatigue. If FRP is to become widespread as reinforcement, these issues must be addressed and resolved.

Pre-Engineered Structural Systems

FRP can be used to create structural systems that have enough strength to resist service loads, and can decrease life-cycle costs as compared with traditional materials. Especially, the components can be manufactured off-site, significantly reducing on-site construction time and increasing quality control. Using the pultrusion process, manufacturers can create almost any constant-cross section shape they like, allowing them to be creative with the structural members and connections they use. Typically, these systems are unique to the designer and manufacturer, as no standards have been developed for these systems.

The Benefits

The benefits include: low weight, high strength, ease of erection, and corrosion resistance. These factors combined lead to lower install costs and lower maintenance costs. When the manufacturing process is perfect and the standards have been developed, the initial costs may be lower as well. All of these factors could lead to lower life-cycle costs than using traditional materials.

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Status

For the applications of structural shapes in FRP, several companies have manufactured the structural shape products, such as Mitsubishi Kasei Corporation in Japan. However, currently the building codes do not allow the use of these members due to a lack of testing for properties strengths.
For concrete reinforcing, FRP has been used in many applications as a reinforcing bar, especially in harsh marine environments where its full potential can be exploited. One example of this use is concrete subbeams of the ground floor of a three-story apartment house built by Mitsui of Japan. 3-D meshes have been used by Kajima Co. as concrete reinforcing for a 23 story building in Japan.

FRP prestressing and post-tensioning of concrete structures is currently the most widely used application of FRPs. One example in Canada is a highway bridge in Calgary, Alberta. Carbon FRP (CFRP) was used to prestress the two-span, bulb-Tee sections. It was opened to Traffic in 1993 and undergoes continuous monitoring of its structural integrity. Another example that uses FRP for prestressing is a concrete berth built by Sumitomo Construction Co., Ltd. in Japan. FRP rods were used for prestressing simply supported hollow girders used in a barge. An example related to post-tensioning is a bridge in Marienfelde, Berlin, that uses glass FRP to externally post-tension the structure.

A major effort is undertaken to develop new hybrid and all-composite construction methods. Among the hyprid structures are concrete piers reinforced with rebars and glass fiber reinforced pulltruded rods. Moreover, carbon fiber reinforced composites sheets are laid into the deck construction of new bridge or the replacement of the damaged steel or concrete decks, and new bridge columns are being wrapped with carbon reinforced composites sheets. The first short-span road bridge was built in Russell, Kansas, which was opened on Nov. 9, 1996. It was designed and fabricated by all fiberglass composite and performed as well as steel or concrete bridges. The first all-composite full service bridge is currently being built at an estimated cost of 55 million dollars to connect two parts of UC San Diego campus over interstate I-5, began from 1996 (Wallenberger, 1995). Other examples include several footbridges crossing streams and rivers in Western U.S. national parks. Composites were chosen for these bridge because they are environmentally friendly in their materials and construction techniques.

Barriers

One barrier to the widespread use of these technologies using FRP materials is that they have not been broadly accepted by building code authorities. Some concerns still remain about FRP's fire resistance, long-term creep characteristics, and failure mechanisms. Also, every manufacturer of FRP uses a different combination of resins, fibers, and geometry. This has led to significant difference from brand to brand, and no set of standards (ASTM, AASHTO, etc.) has been developed for FRP.

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