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CARBON FIBER REINFORCED POLYMER (CFRP) LAMINATES FOR STRUCTURAL STRENGTHENING

THE NEED

Strengthening measures are required in structures when they are required to accommodate increased loads. Also, when there are changes in the use of structures, individual supports and walls may need to be removed. This leads to a redistribution of forces and the need for local reinforcement. In addition, structural strengthening may become necessary owing to wear and deterioration arising from normal usage or environmental factors.

Concrete structures need to be strengthened for any of the following reasons:

- Load increases due to higher live loads, increased wheel loads, installations of heavy machinery, or vibrations.
- Damage to structural parts due to aging of construction materials or fire damage, corrosion of the steel reinforcement, and/or impact of vehicles.
- Improvements in suitability for use due to limitation of deflections, reduction of stress in steel reinforcement and/or reduction of crack widths.
- Modification of structural system due to the elimination of walls/columns and/or openings cut through slabs.
- Errors in planning or construction due to insufficient design dimensions and/or insufficient reinforcing steel.

THE TECHNOLOGY

The pultruded CFRP laminate reinforcing consists of bonding the CFRP strip with the concrete structure using a high-strength epoxy resin as the adhesive. The CFRP strips are manufactured using a pultrusion process. The pultrusion principle is comparable with a continuous press. Normally 24,000 parallel filaments are pulled through the impregnated bath, formed into strips under heat, and hardened. These strips are uni-directional; the fibers are oriented only in the longitudinal direction. Correspondingly, the strip strength in this direction is proportional to the fiber strength and, thus, very high. Strips are produced with strengths of approximately 3,000 MPa in the longitudinal direction, and with a thickness of up to 1.5 mm and widths of up to 150 mm.

In order to achieve an optimum composite action, the preparation of the bonding surfaces of the strip and concrete is critical. The strips must have the outermost layer of their bonding face, normally matrix-rich, removed to expose the fibers. Just before the bonding, the bonding surface is carefully cleaned with acetone. The concrete surface is treated by sand blasting, high pressure water jets, stoking, or grinding. Shortly before the bonding, it is cleaned with a vacuum cleaner. Concrete must be at least 6 weeks old, and have a minimum tensile strength of 1.5 MPa. Highly filled epoxy resin adhesive is used for the bonding.

THE BENEFITS

CFRP laminate reinforcing technology provides a solution for strengthening problems of concrete structures. It provides great strength, high modulus of elasticity, and outstanding fatigue resistance. It is a very lightweight non-corrosive material, that requires minimal preparation of laminates, and it's alkali resistant. It is an economic method that requires very short contract times.

STATUS

Based on the worldwide research and development work, the use of CFRP strips to rehabilitate structures is already routine for many firms in Western Europe and Japan. In the U.S., Sika has introduced Sika CarboDur, which is a CFRP laminate used to strengthen concrete, steel, or wooden structures. CFRP materials will not replace traditional construction materials, but will be used increasingly to supplement them as needed.

A research team led by Dr. Abdul-Hamid Zureick, Professor of Civil and Environmental Engineering at Georgia Institute of Technology, Atlanta, GA, has performed an integrated field/laboratory approach to rehabilitate the Lee Road Bridge over Interstate 20 in Douglas County, GA, using CFRP. This project is funded by the Georgia Department of Transportation (GDOT) in cooperation with the Federal Highway Administration (FHWA). The project took workers less than a day to complete what could have taken several weeks to do traditionally and, so far, laboratory tests have determined that CFRP can make bridges 30 to 40 percent stronger than the original design.

BARRIERS

Although this technology has been used successfully in Japan and Europe, the usage of composite materials like CFRP is still not widely recognized in the industry. The lack of knowledge of the technology and the simplicity of it will make some people hesitant to use it.

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REVIEWERS

Peer reviewed as an emerging construction technology

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