

# Carbon Fiber Reinforcing

Making Double Tees in Parking Structures Lighter and Stronger

By Harry A. Gleich, P.E., F.A.C.I., F.P.C.I.

Parking structures represent one of the most demanding applications for concrete. They're exposed to the weather 24 hours a day, seven days a week. They're expected to support hundreds or even thousands of vehicles, including today's heavyweight SUVs. And they're constantly exposed to corrosive agents such as salt used to clear roads during winter and chloride-laden air and moisture along the coastlines, or both in places like Boston and New York City.



*Especially in demanding regions like those near marine environments, garage decking is susceptible to problems related to the corrosion of reinforcement*

Regardless of their source, chlorides have the potential to cause corrosion in some of the steel reinforcing, generally the secondary flange reinforcement. When the steel corrodes, it more than doubles in volume and can cause cracking or spalling as well as unsightly staining – problems the building or garage owner would like to avoid. Corrosion isn't a problem everywhere, but in geographic areas where it is common, it has the potential to be a garage owner's worst nightmare.

A new approach to reinforcing double tee flanges involves the use of carbon fiber grid as a replacement for conventional steel mesh reinforcement. Carbon fiber is non-corrosive which virtually eliminates the problems noted above, as well as the cost of admixtures and barriers used to inhibit corrosion. At the same time, carbon fiber reinforcement can reduce the amount of concrete necessary in the flange—leading to a 12 percent reduction in double tee weight—without compromising structural performance; the flanges have been tested for both point loads and uniform loads to meet the test load requirements of both IBC and ACI.

## High-Tech Fibers Come to Precast

Say the words “carbon fiber” and most people think of items such as jet fighters, tennis racquets, bicycles, golf clubs and motorcycle components. Within the past decade, manufacturers have developed lower cost, industrial-grade carbon fiber for broader use in demanding construction applications. As a result, the precast concrete industry has been able to benefit from the same outstanding strength-to-weight ratios and durability characteristics that have made carbon fiber an ideal material to take a jet fighter to Mach 2 or propel Lance Armstrong through the French Alps.

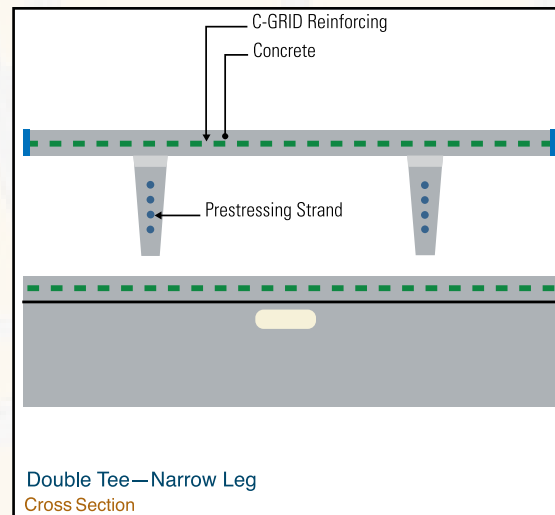
As a lightweight, non-corrosive “enabling technology,” carbon fiber grid reinforcement allows double tees to be lighter, more durable and often less costly in the long run than conventional precast products that rely on steel reinforcement. Exceptionally strong, carbon fiber delivers 6,000 lbs/lf of strength (comparable with steel reinforcement used in reinforced concrete design) and has tensile strength over five times that of steel. (Different strengths are available, though the strength is consistent throughout the same sheet.) A carbon fiber grid displays linear elastic behavior until failure. Epoxy coating chemistry and small-aperture grid design provide excellent bonding to concrete and superior crack control.

## Carbon Fiber Reduces Concrete Cover

To minimize corrosion of steel reinforcement, double tee manufacturers incorporate concrete cover into the flange to protect the steel mesh from water and corrosive chemical compounds. In fact, most pretopped double tees have a minimum flange depth of 4 inches to provide ample cover for the steel mesh. In many cases, manufacturers put more concrete in the flange than is necessary to support expected loading. The extra concrete protects the reinforcement. It also adds weight, which until now has been largely unavoidable.

Because carbon fiber is corrosion-resistant, it allows precast manufacturers to reduce the amount of concrete cover in each double tee flange by up to  $\frac{3}{4}$  inch. Conventional prestressed strands in the stems are protected by more than 12 inches of concrete as measured from the top of the flange.

Reducing the flange thickness by  $\frac{3}{4}$  inch removes 9 pounds per square foot of dead load, which can either provide more reserve capacity or reduce the amount of prestress required. And by eliminating the need to add cover over the reinforcement to resist corrosion, precasters can optimize the position of the reinforcement, moving it closer to the top surface of the flange to maximize performance and provide even better crack control. By moving the reinforcement toward the top of the flange, precasters have been able to provide up to 2  $\frac{1}{2}$  inches of



*Because carbon fiber is corrosion resistant, it allows precasters to reduce the amount of concrete cover in each double tee flange by up to  $\frac{3}{4}$  inch*

structural concrete below the mesh reinforcement, compared to only 2 inches of concrete in typical precast double tees – important because the flange is designed as a prop cantilever.

## Strong and Durable Reinforcing

Protecting the steel mesh reinforcement in conventional concrete double tees costs money. A number of chemical treatments are typically used during double tee fabrication and after installation to inhibit and delay the corrosion of steel mesh in the flange.

With non-corrosive carbon fiber reinforcing, manufacturers can avoid the cost of sacrificial barrier coatings on the steel and eliminate the need to add corrosion inhibiting admixtures to the concrete. Meanwhile, owners can forego the application of sealers to the precast deck surface after installation and also avoid re-applying these sealers every five to ten years.

From an initial cost standpoint, carbon fiber tends to be more expensive than steel mesh. However, when one considers the increasing cost of steel, the cost for corrosion inhibitors, potential reductions in substructure and site costs, and increased life span, carbon fiber reinforcing can lower life cycle costs dramatically, especially after the first decade of operation.

Laboratory testing has affirmed the performance of double tees with carbon fiber reinforcement. Load testing demonstrates they can stand up to the heaviest sport utility vehicles. Fire tests confirm that they can meet ASTM E-119 fire rating for one-hour performance, and calculations show that, just like steel mesh reinforced tees, they can provide a two-hour fire rating with 4 5/8 to 4 3/4 inch thick flanges. Test reports are available.

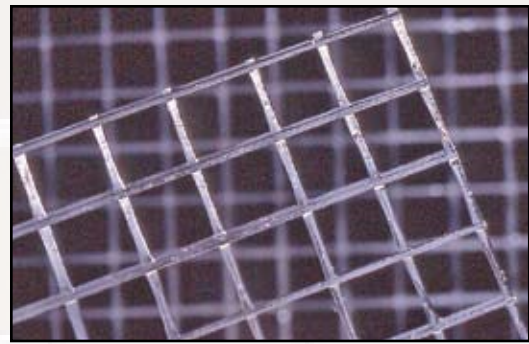
## Practical Applications

A 270,000-square-foot, four-level parking structure in suburban Milwaukee has carbon fiber reinforced double tees on the top deck. The owner, a developer that leases to a Fortune 500 company, opted for carbon fiber reinforced double tees because of their long-term durability and resistance to corrosion. The owner's choice was especially important considering the top deck is exposed to Milwaukee's harsh weather, everything from ice storms and severe snow to summer heat waves. The 15-foot wide double tees have a two-hour fire rating to match the balance of the garage.

Another precast project, designed to replace a badly corroded, condemned cast-in-place structure located near the New Jersey shore, is also being constructed with pre-topped carbon fiber reinforced double tees. Several other projects are currently in the engineering and evaluation phases.

## A New Technology... A New Delivery Model

The application of carbon fiber reinforcement heralds the first major advancement in precast technology in decades—perhaps since



*Carbon fiber delivers 6,000 lbs/lf of strength and has tensile strength over five times that of steel*

the introduction of precast itself. Several of the nation's leading precast companies have collaborated to develop, test and market carbon fiber reinforced products such as pretopped double tees, architectural cladding panels, high performance insulated wall panels and precast components for residential uses.

Their partnership establishes a new model for the introduction of new technologies to the precast concrete industry. By pooling resources, expertise, and technical knowledge, and by working together to develop best practices, these companies have expedited the introduction of carbon-fiber reinforced precast concrete. The daunting cost and time to bring this technology to market could have been too much for one company to absorb. But as a collaborative unit, the partner companies' commercialized carbon fiber reinforced precast concrete in only two years.

The use of carbon fiber reinforcement is an important innovation because it promises improved corrosion resistance by eliminating steel reinforcement in double tee flanges. Compared with conventional precast concrete, poured-in-place and other options, carbon fiber reinforced pretopped double tees can deliver reduced weight and life cycle improvements, especially in highly corrosive environments.

It is likely that the use of carbon fiber reinforcement will grow in popularity as its effectiveness is validated by a variety of installations. With architects and engineers clamoring to be the "first one to be the second one in," carbon fiber reinforcement should gain a rapid following as the innovators give way to early adopters and the early majority – and possibly one day make this novel precasting technology the new industry standard. ■

*Harry Gleich, VP of Engineering for the Metromont Corporation, has more than 20 years experience in the precast concrete industry. He is an active member in the Precast/Prestressed Concrete Industry (PCI), having served on the several PCI Design Handbook Committees and currently as Chairman of the Parking Structures Committee. He is a member of the technology committee and board of directors for AltusGroup, a partnership of precast concrete manufacturers that have collaborated to expedite the commercialization of carbon fiber reinforced precast concrete.*



*A 270,000-square-foot, four-level parking structure in suburban Milwaukee uses carbon fiber reinforced double tees*

**ALTUSGROUP** IS A CONSORTIUM OF LEADING PRECAST COMPANIES COLLABORATING TO DEVELOP, TEST AND MARKET CARBON FIBER REINFORCED PRODUCTS. THIS COLLABORATION HAS ENABLED THE FIRST-EVER NATIONAL ROLLOUT OF A NOVEL PRECAST BRAND, CARBONCAST. ([WWW.ALTUSPRECAST.COM](http://WWW.ALTUSPRECAST.COM)) MEMBERS OF THE ALTUSGROUP INCLUDE: OLDCASTLE, HIGH CONCRETE GROUP, METROMONT CORPORATION, GATE PRECAST, SHOCKEY PRECAST GROUP, BLAKESLEE PRECAST, HELDENFELS ENTERPRISES AND MORSE BROTHERS.