Stressing the Importance of Permanent Strengthening

Parking Garage Cracking Meets its Match with Carbon Fiber Reinforcement and Repair

By Joseph L. White

Stress has been one of the primary considerations in construction since the beginning of time. When applied correctly, stresses can leverage the load-bearing potential of a wide variety of building materials. However, when misapplied, calculated incorrectly or created by outside factors, stresses can also hasten the failure of building materials, and potentially threaten the integrity, functionality and overall safety of a structure.

Parking garages — and in particular, those constructed of concrete components — can be particularly susceptible to the negative effects of stress. If not designed correctly, movement-induced stresses can result in concrete cracks. These cracks can reduce load carrying capacity, create the potential for leakage and facilitate intrusion of chlorides and other harmful chemicals into the structure. Chloride and chemical intrusion into the structure can ultimately degrade the reinforcements within the concrete components and cause pre-tensioning within beams and other structural members to be compromised.

When stress cracking is identified in a parking garage, it's critical to quickly identify the cause of the problem and correct it. Rather than turn to traditional reinforcement methods involving additional steel and concrete, a growing number of parking garage owners are relying on carbon fiber reinforcement products to supplement the existing load capacity of their structures, and permanently and cost-effectively reinforce and repair stress cracks.

Carbon fiber reinforcement technology has been used since the late 1980's on a wide variety of structures. Originally applied to bridges to increase their load-bearing capacity, carbon fiber has found favor in the parking garage marketplace due to its exceptional strength and ease of application. Available in laminate or a fabric forms, carbon fiber reinforcement can be applied to carefully prepared concrete surfaces using specially formulated epoxies. The laminate is typically the choice for repairs to linear concrete surfaces, while the fabric is best suited for non-linear surfaces.

Up to 10 times stronger than steel reinforcement, carbon fiber reinforcement is ideal for parking structure applications, because it is:

- lightweight
- easy to handle and apply
- completely inert and non-corrosive

"One of the greatest benefits that composites offer over traditional steel plate bonding, is that carbon fiber materials provide an extremely favorable strength-to-weight ratio without adding noticeable dead weight to the structure," says Dave White, P.E., director of Technical Services at SIKA Corporation, one of the leading producers of carbon fiber reinforcement systems in the world.

"Parking structures typically cannot support a lot of extra dead weight due to their design. In addition, because headroom is limited, it's not really an option to deepen beams by adding additional concrete and steel without compromising vehicle clearances. In most garages, a reduction in headroom by only three to four inches can limit what vehicles can use a garage. Composite materials are exceptionally strong, but low in profile. As a result, you can strengthen a structure and might only subtract one-half inch of headroom. And unlike steel reinforcements, with carbon fiber, you don't have to be concerned about rusting or corrosion. Which means you won't have to be as concerned about ongoing maintenance on the reinforcement materials you installed."

It All Begins with the Bondline

While carbon fiber materials are lightweight and easy to handle, the success of an installation rests on the quality of the bond between the existing concrete and the reinforcement.

"You need to be diligent about thoroughly preparing your surfaces, because the bond between the concrete and the epoxy is the key to making a carbon fiber installation work," says Will Gold, Engineering Services manager at BASF, another leading manufacturer of carbon fiber reinforcement systems. "Before any epoxy is applied, spalls or cracks need to be repaired, and any corrosion on the reinforcement strands needs to be completely removed. The last thing you want is to have the concrete continue to deteriorate behind the epoxy. When surface repairs have been made, the entire concrete surface must be cleaned and roughened by either blasting or grinding it to strip away any weak surface layers of concrete and to remove oils, greases and dust. When it's all said and done, you want to have a bit of tooth on the concrete for the epoxy to bond to."

Performing pull tests by a certified testing agency are essential in ensuring the desired bond line adhesion which is critical for the intended application's performance.


Application at precast double tee stem ends.

It's also critically important to install the carbon fiber material so the fibers are running in the right direction. "Carbon fiber is anisotropic, which means the material has different strength properties based on the direction that it's installed," says Gold "While steel can be used in any direction, a carbon fiber reinforcement is only going to be effective when it's installed in the direction specified by an engineer. If you apply the material against the grain, you won't get much strength and won't achieve the desired results."

To ensure that the carbon fiber material is installed correctly, working drawings are developed that clearly specify the direction of the material when it's installed at the repair site. The installer must follow these specifications to the letter to achieve the necessary reinforcement qualities.

Once installed, the lifespan of a carbon fiber repair is typically predicted to last 50 years or more. While the carbon fibers themselves can last hundreds of years, the longevity of the repair directly depends on the lifespan of the concrete it's bonded to. In addition, there really is no ongoing maintenance with carbon fiber reinforcement, other than occasionally coating the material for cosmetic reasons. When selecting coatings, however, it's essential to choose materials that will bond to – but not damage or degrade — the epoxy. For example, coatings with high levels of solvents that have the potential to compromise the epoxy should be avoided. Manufacturers of carbon fiber reinforcement systems typically can recommend or supply appropriate coating materials.

Overhead application at hospital to strengthen floor for high density filing system.

Application of a fire-rated colored coding on precast units.

The Experience Factor

Both White and Gold agree that when it comes to the installation of carbon fiber reinforcement materials in parking garages, Pittsburgh's Carl Walker Construction is one of the most experienced firms in the marketplace. "It's hard to find a structure that doesn't have some level deterioration going on. Carl Walker Construction is one of the leading concrete repair firms, and they know how to apply carbon fiber products correctly," observed SIKA's White. "They also have years of experience in working with polymers and epoxies, and know how to overcome installation challenges."

Joseph White (no relation to the SIKA representative), managing partner at Carl Walker Construction, concurs with the SIKA representative. "We have been applying carbon fiber reinforcement systems for more than 11 years, and we've found them to be some of the most cost efficient and effective ways to address cracking problems and increase the load carrying capacity of a garage," he says. "Carbon fiber reinforcement is also excellent for use in structures where the intended use — and the structural loads associated with that use — have changed. While carbon fiber products might cost slightly more at the outset, the long-term performance and relatively straightforward installation make it possible to perform essentially maintenance-free, permanent repairs in a relatively short period of time. Typically, we can keep a parking garage in operation while we're installing carbon fiber reinforcements. Many times, you just can't do that if you're adding steel or additional concrete."

Recently, Carl Walker Construction completed structural strengthening work on two West Virginia parking structures. Both structures, which coincidentally are owned by hospitals, were constructed of precast components approximately 40 years ago. In each garage, structural components were strengthened with carbon fiber reinforcement technologies when cracking was found in precast beams or structural members.

The first structure had beam cracks in 34 locations throughout the seven-story, 1,200-car garage. Carbon fiber laminates were applied to each compromised beam using a high modulus, high-strength epoxy resin. This successfully reinforced the cracked components, and since carbon fiber laminates are only 1/32" thick, they had little to no impact on headroom. The work took approximately nine weeks to complete from start to finish, and the entire garage was kept open during the $700,000 repair project.

At the second project, carbon fiber wrap was installed with high modulus, high-strength impregnating resin around cracked columns. The wrap was also used to reinforce the stems of double Tees supporting three elevated parking

levels. In addition, wrap material was used to strengthen the undersides of the double Tees along the flanges of the precast units. In total, the $3,100,000 job used more than 25,000 square feet of carbon fiber wrap to reinforce the structural components in the 200,000 square-foot, 600-car garage. The repair was completed in 18 months.

Another company project, the reinforcement and repair of the precast parking garage at a well-known airport in the country, ranks among the largest carbon fiber reinforcement installations in the world.

"We did extensive work on this parking garage to correct a number of serious structural problems that cropped up soon after it was built in the early 1990's," says White. "Repairing and reinforcing the garage with carbon fiber saved the owner a significant amount of time and money over traditional methods, and also allowed airport management to keep this vitally important garage open to airport patrons."

Crack Repairs Are Critical

Len Tsupros, president of Carl Walker Construction, reiterates that time is of the essence when it comes to making carbon fiber repairs to a parking garage. "Cracking is a fact of life in nearly all concrete parking structures," he observed. "The sooner you address the cause of the cracks — and the sooner you execute a carbon fiber repair, the less likely you are to have major and costly structural problems further down the road. The choice is to pay a reasonable amount now to make the repair, or an astronomical amount later to reconstruct the garage. Given our expertise with carbon fiber reinforcement installation, and the excellent long-term performance properties the products deliver, the choice really becomes obvious."

Joseph L. White is vice president of Carl Walker Construction, with more than 27 years of industry experience. He is responsible for all of Carl Walker Construction's restoration, carbon fiber, waterproofing, expansion joints between joint sealants and waterproofing systems, as well as specialty projects. White has managed every carbon fiber project with Carl Walker Construction. He can be reached at **jwhite@carlwalkerconstruction.com.**