Carbon Fiber Reinforcement for Concrete

by Cameron Brochu, UNH - Civil Engineering

It is well known that concrete is one of the most widely used construction materials and its applications have produced some of the most incredible structures the world has ever seen. However, it does have some limitations and problems that can be attributed to the material’s brittle properties; concrete is very strong in compression, but relatively weak in tension. In order to increase the concrete’s tensile strength, internal reinforcement is often necessary.

Continued on page 4
The New Hampshire Technology Transfer Center is in the midst of the 2013 Spring Training season and is offering more than fifty days of workshops and training between the end of March and the beginning of July this year. We are offering training in some of the traditional areas, but have added a few new workshops in the past few months including: First Aid, CPR & AED Training; OSHA Roadway Construction 10 Hour Training; Confined Space and Trench Safety; Becoming a Supervisor; and Harassment Prevention. There are already plans to include more new workshops this fall.

It is an exciting time to be a part of our Roads Scholar Program! In 2012 we had more than 100 people achieve a new level, congratulations to all! T² put out a Roads Scholar Directory in February 2013 to reflect all our Roads Scholars’ current level status. If you’d like a copy of this directory, please contact the office. We hope that you continue to grow and achieve.

T² is also branching out and participating in aspects of local roads in new ways. We have been working closely with the Federal Highway Administration New Hampshire Division to help promote and spread the initiatives of Every Day Counts. T² has been working closely with the NH Department of Environmental Services on our Green SnowPro Certification for reducing salt usage in winter maintenance and more recently in developing a Culvert Certification Program for municipal crews to maintain and replace culverts up to 48 inches. The Center has also worked very closely with the NH Public Works Association in its new merger with other public works associations to help create a unified voice and organization for public works in the State of New Hampshire. We hope to continue to serve those who work on our local roads in the coming year!

Sincerely,

Beth Hamilton
Training Program Manager
Technology Transfer Center
This past December, we celebrated the graduation of our newest Master Roads Scholars. During the year of 2012, we had more than 30 new people achieve Master Roads Scholar. To all of you, congratulations! Your dedication to your job, continuing education, and our program is appreciated by the citizens driving on our roads, our staff, and the people of your community.

The Technology Transfer Center will be releasing a Roads Scholar Directory in early January to highlight all of our Roads Scholars level of achievement. We’ve had more than 90 people achieve new levels in our program in 2012. We are proud of all our students’ achievements and hope to see even more in the future!

If you have a question about what level you are at, what the levels are or what is printed on your transcript, please do not hesitate to call Amy Begnoche at the office at 603-862-2826.
Carbon Fiber Reinforcement for Concrete

**Steel: An Imperfect Solution**

Steel has long been used as reinforcement in concrete construction and steel rebar is the most common form in production today. Although steel is very strong in tension and makes an excellent reinforcing material, it also suffers from a few limitations. It is susceptible to corrosion during the curing process, byproducts of which could significantly compromise the integrity of the concrete structure. Steel is also very dense, which makes it a very heavy material to ship and place and makes the reinforced concrete heavier to place and support.

In today’s construction and design fields, the recent trend has been utilizing new materials and technologies to build better structures with less material. One of the most promising of these developing practices is fiber reinforced concrete (FRC). UNH T2 Director Dr. Charles Goodspeed has been one of the area’s largest supporters of its use in local projects. In an interview with the Director, I explored the upsides, problems, and applications of this emerging material technology.

**Short Carbon Fibers**

The first attempt at creating FRC consisted of mixing small carbon fibers about 1 centimeter in length into the concrete. Studies have shown that the fiber’s high tensile strength provides resilience to the cast concrete and can increase flexural strength and toughness with concentrations of only 0.05% of the cement weight and 0.189% of the concrete’s volume.

The down side of using short fiber is that the fibers are only effective post-cracking. This means that although a slab may have a higher flexural strength, adding small fibers to the concrete mix does not increase its carrying capacity and resistance to ruinous cracking. Although this method proved all but useless in most applications, this was only the beginning for FRC.

**Carbon Fiber and Fiberglass Rebar**

The next step in the evolution of fiber reinforcement was the development of carbon fiber reinforced polymer (CFRP) and fiberglass rebar. Placed similarly to their steel counterparts, these reinforcement rods provided good strength increase to concrete with less weight than steel. The only down side was that the manufacturing process produced smooth bars that did not adhere well to curing concrete to provide the necessary tensile strength.

One of the ways engineers helped increase friction and grip between the fibrous bars was by deformation. With deformed CFRP rebar, string is wound around the freshly formed bar and tightened to form a spiral-patterned indentation in the bar that the concrete can expand into as it cures. The deformation helped, but
more tensile grip was necessary so the CFRP bars were also given a rough, coarse fiberglass coating that increased friction between the bars and the concrete.

Although the deformed, coarse fiberglass coated CFRP rebar has shown promise, some concerns exist about its durability. One of Director Goodspeed’s major fears about it is that the coarse coating may wear off. During the interview, he rubbed two CFRP bars (that he happened to have on hand) against one another and showed how easily the fiberglass crystals scraped off. “If that happens in the concrete after it’s placed, then you’ll really be in trouble,” said the Director. A close-up of the coarse coating is shown below.

Another issue about fiberglass rebar durability arose from a University of Florida study in which a test specimen was half submerged in concentrated seawater. The “splash zone” section of the rebar that was exposed to wetting and drying cycles during lab testing deteriorated quickly, raising concerns about the material’s resistance to common chlorides and sulfates.

**Carbon Fiber Grid Reinforcement**

One of the latest innovations in CFRP is the concept of reinforcement grids. These are layered carbon fiber grids that come in sheets manufactured to various thicknesses. As with traditional rebar, they are cast into the concrete with specified depths and cover thicknesses. But unlike steel or CFRP rebar, these grid sheets can be laid down quickly and easily and are light enough for one worker to carry and place. In addition, they are highly resistant to corrosion from sulfates and road salts.

**CFRP Case Study: Rollins Road Bridge, Rollinsford, NH**

Built in 2000, the 110-foot Rollins Road Bridge spans Main Street and the Boston-Maine Railroad in Rollinsford, NH. With support from the Federal Highway Administration’s (FHWA) Innovative Bridge Research and Construction (IBRC) program, The NH Department of Transportation (NH DOT) and the University of New Hampshire (UNH) collaborated to design a reinforcement system made from CFRP grids.

The entire deck of the bridge is reinforced for both positive and negative bending with 9’ by 7’ grids. The system, designed to provide the same ultimate strength of Grade 70, #6 steel rebar, uses individual grid spacing similar to that of traditional concrete reinforcement. Also installed during construction were several fiber-optic strain gauges to precisely measure any deflections in the bridge.

In late June, I paid a visit to the bridge to see
for myself how the carbon-fiber reinforced deck was holding up. After 12 years of service and exposure to coastal New England weather, the entire bridge appears virtually flawless. The deck, although beginning to experience minor rutting, is smooth and shows no signs of cracking. The support structures on each end are in excellent condition. Only the unreinforced facial slabs on the sides and girder cross members exhibit any cracking at all.

Data recorded by the fiber-optic gauges in 2002 showed that after 2 years of service and sustained traffic load, the deck and girders only deflected 0.1” (2.5 mm). This impressively low strain value reflects the bridge’s sound design as well as the effectiveness of the CFRP grids as structural reinforcement.

**Versatility**

Perhaps the most beneficial aspect of the carbon fiber grid reinforcement is its great versatility. Not only is it a desirable option for bridge and infrastructure projects, but it can be used in many places where traditional rod reinforcement would not be feasible.

In the case of concrete walls, it can be very difficult to keep vertical steel rebar in place while casting. However, the simplicity of the one-piece construction of CFRP grids makes this process much easier. Thin concrete walls like the ones shown in the diagram at left are examples of situations where carbon fiber grids can make the use of concrete possible where it may not have been due to the difficulties associated with traditional rebar. This kind of versatility not only suggests the future success of CFRP, but revolutionizes the types of potential applications for reinforced concrete in future construction projects.
high school students at New Hampshire Construction Career Days (NHCCD).

NHCCD is a fantastic event that exposes New Hampshire high school students to possible career paths in both the construction and transportation industries through hands-on exhibits and educational resources. Labor unions, construction and engineering companies, trade and professional organizations, and state agencies collaborate to provide students with an introduction to various aspects of construction.

This two day event (4th year running) will be held September 19th & 20th at the Hopkinton Fairgrounds. Last year 39 schools participated with over 900 high school students attending. These students had a wonderful opportunity to take part in hands-on activities with over 50 exhibitors including welding, carpentry, heavy equipment, tree climbing, surveying, plumbing, truck driving simulators, post-secondary education opportunities, and many more.

Students can operate the controls of an excavator, zero in on targets with a total station, or practice welding alongside a professional to get a feel for a future construction related career. One student stated, “You were able to actually use the equipment and talk to the people about what they do and their job atmosphere.” NHCCD also encourages students to explore colleges and career training programs. Professionals from a wide array of construction-related work are available to speak with students and answer questions about their experiences in the construction industry and why they are so passionate about their career. “I liked how everybody there was very friendly and helpful. It was because of them that it was a very fun, hands-on experience,” stated another student.

A teacher from one of the participating schools commented, “This is the favorite field trip for most of my students. They are actively engaged, and it is relevant to their future. One of our female students was hired as a result of participation in New Hampshire Construction Career Days.” By reaching out to as many high school students as possible, attendees are able to increase their career awareness in the transportation and construction industry.

NHCCD is looking for engineering companies to participate in this exciting event, since construction and engineering go hand-in-hand. As a member of both the NHPWA and ASCE, a female Civil Engineer, and one of the NHCCD Coordinators, I ask that you join me in expanding the engineering exhibits or volunteer to run a mini-engineering challenge for students. There are many great ideas from the Massachusetts Construction Career Days event that have been widely successful at sparking interest with students. It is critically important as mentors that we encourage high school students to think about careers in engineering.

This event is only possible because of the generous sponsors and volunteers. Because of you, the youth of today will be building the New Hampshire of tomorrow. If you would like more information, please visit our website at http://nhccd.weebly.com. I would be happy to speak with any of you about participation in this event. Thank you all for considering this opportunity to mentor students for a day!
**New Hampshire Roads Scholars**

Master Roads Scholar is the fourth and highest achieving level of the UNH T² Center Roads Scholar Training Program. To be a Master Roads Scholar, the participant must have completed 100 training hours, including the requirements for Roads Scholar Level II. The third achievement level of the program is becoming a Senior Roads Scholar. Senior Roads Scholars have completed 75 hours of training including the requirements for Roads Scholar Level II. Roads Scholar Level II requires 50 hours total, including 25 hours in technical training, 5 hours of supervisory training, 5 hours of tort/liability or safety, and 5 hours dedicated to environmental training. The first achievement level is Roads Scholar Level I. To achieve Level I, participants must complete 25 hours of training. We congratulate all those who have reached new achievement levels and encourage further training in the future.

**Roads Scholar I**
25 training hours in the Roads Scholar Program

- Larry Anthony, Concord
- Edward Atkins, NHDOT
- Mark Beal, Richmond
- David Campbell, NHDOT
- Gary Clifford, NHDOT
- David Defosse, Washington
- Gregory Dow, NHDOT
- Adam Dunning, NHDOT
- Jeremy Gibbs, Conway
- Michael Gingras, Rochester
- Jim Hoffman, Pelham
- William Kennett, Conway
- Gary Leblanc, NHDOT
- Michael Lockard, NHDOT
- Kevin Marter, NHDOT
- Matthew McLain, Weare
- Patrick Meehan, Merrimack
- Patrick Mullaly, Portsmouth
- Jim O’Donnell, NHDOT
- T.J. Rosatto, Colebrook
- Carl Ruel, NHDOT
- Jeremiah Sargent, Plymouth
- Summer Scott, Farmington
- Frank Simpson, Rumney
- Justin Smith, NHDOT
- Wayne St. Laurent, NHDOT
- George Tessier, Lebanon

**Roads Scholar II**
50 training hours and Roads Scholar II requirements

- Jack Tyrell, NHDOT
- Richard Wendell, Bridgewater
- Richard Anderson, Conway
- Lance Foss, Conway
- Kevin Minckler, Claremont
- Robert Scott, Canaan

**Senior Roads Scholar**
75 training hours and Roads Scholar II requirements

- Duane Abbott, Sunapee
- Randy Borelli, Derry
- Bob Gray III, Conway
- Mike Hammond, Lebanon
- Benji Knapp, Weare
- Louis Lapointe, Merrimack
- Dan Miller, Claremont
- Carl Peare, Weare
- Mike Rau, Claremont
- Charles Seamans, Claremont
- Michael Stack, Weare
- Joe Troy, Weare
- Frederick Wallace, Weare
- Jeff Wright, Weare

**Master Roads Scholar**
100 training hours and Roads Scholar II requirements

- Ralph Barrett, NHDOT
- Dave Bogannan, NHDOT
- William Buxton, NHDOT
- Jere Calef, NHDOT
- Christopher Carazzo, NHDOT
- Scott Daley, NHDOT
- Ernie Doucette, NHDOT
- Joseph Fagnant, NHDOT
- Robert Golemo, NHDOT
- Leon Holmes, Jr., NHDOT
- Bruce Kimball, NHDOT
- David Lacasse, NHDOT
- Jody McDonald, NHDOT
- Greg Messenger, NHDOT
- Robert Meunier, NHDOT
- George Morngan, Jr., NHDOT
- Steve Paul, NHDOT
- Ricky Plankey, NHDOT
- Jason St. Cy, NHDOT
- Steve St. Pierre, NHDOT
- Dean Stears, NHDOT
- Rober Trempe, NHDOT
- John Trythall, NHDOT

Have a question about what level you have achieved or what workshops you have taken? Contact Beth Hamilton at 603-862-1362 or e-mail t2.center@unh.edu to request information regarding your Roads Scholar transcript.
The 7th Annual Ken Ward Memorial Snow Plow Rally took place September 19th at the Hopkinton State Fairgrounds in Hopkinton, NH. The competition attracted over 180 municipal workers and exhibitors who enjoyed cheering on their favorite teams, as well as Bar-B-Q lunch.

There were 15 municipal teams that competed. First place went to the Town of Weare’s team Benji Knapp and Jeff Lewis. Knapp and Lewis are no strangers to the “winner’s circle” having won the competition most recently in 2010 and placing 2nd last year. Steve Perry and Moses Delphia (Town of Hanover) took second place.

The Champion Municipal team then went up against the NH DOT Champs, Ben Kenney and Jared Cloutier. Knapp and Lewis prevailed once again, however, and were crowned NH State Champions! They now will go onto compete at the New England Regional Competition in Leominster, MA on November 7, 2012 against other State Championship teams from throughout New England.

The Dana Wright Backhoe Competition was also held during the Plow Rally. From the nearly (25) competitors, just two had perfect scores. Benji Knapp (Town of Weare) finished in First Place by besting Second Place winner Charles Nichols’ time (City of Keene) by nearly 4 minutes!

Congratulations to all. Hope to see everyone back next year, Wednesday, September 18, 2013.

For any further information please contact: Catherine Schoenenberger, Stay Safe Traffic Products, Inc., stay-safetraffic@aol.com, 866-692-2114.
2013 National Work Zone Awareness Week

We’re All In This Together

Work Zone Safety
NH Public Works Memorial

by Bill Boynton, Public Information Officer, NH Department of Transportation

“I can remember it like it was yesterday.”

It was May 25, 1959 and Jim Rivers was 9 years old.

“My mom got a call and they said my dad was injured on the job. I was waiting in the yard when Louis Colgan from the State Highway Department drove up and told my mother, “I think we better go inside.”

Ephriam Rivers, or Steve as everyone called him, was a foreman in the Traffic Division, which installed and maintained traffic lights and beacons across New Hampshire. He was working at the General Sullivan Bridge in Newington-Dover when a crane cable snapped and a lamp post fell on his head, killing him. Steve Rivers was 35 years old.

“My last memory of my father was sitting on his lap watching television on the night before he died,” Jim Rivers says. “It changes your life forever. Your life takes a different path,” according to the longtime New Hampshire radio broadcaster and state employee. “My mother had to go to school to become a hair dresser.”

Mark W. Richardson was home from college and the rest of the family was still sleeping on the day after Christmas in 1973. Early that morning his mother was visited by a local police officer, who gave her the bad news.

Mark’s dad, Carl Richardson, was a Highway Maintainer and light equipment operator at the New Hampshire Department of Public Works and Highways working out of the Alton Patrol Shed. On Christmas night, as he had done so often, Carl responded to an ice storm to treat the highways. He was shoveling road salt in the back of a plow truck when the truck rolled over on NH Route 140.

“It wasn’t unusual for my father to be called out for a day and a half during a typical storm,” Mark Richardson recalls. “We were used to him being gone for long hours during winter storms, but of course assumed that he would always come home – only this time he didn’t. He was only 47 years old when he died, and even after nearly 40 years, he is still greatly missed. It is rare for a day or more to go by without my having thoughts and memories of him,” Mark says.

Carl Quiram knows these stories all too well. The Goffstown Public Works Director has felt strongly for many years that public works employees who have died while doing “critically important work” for the citizens of New Hampshire should be honored in some way. Quiram was part of a small group who pushed for and received legislative approval for a Public Works Employee Memorial.

“We envisioned a memorial as a way to honor those who fell in the line of duty,” Quiram says. "It’s a way to remember the sacrifices they made for the safety of all of us.”

“I can remember it like it was yesterday.”
who have made the ultimate sacrifice, and also to raise safety awareness about the hundreds of workers who are out there every day. It is still a dangerous job,” Carl Quiram says.

On June 15, 2009, Gov. John Lynch signed into law a bill “establishing a committee to oversee the design, construction and maintenance of a memorial to public works employees who have died in the course of performing public works duties on behalf of a municipality, a county or the state.”

The resulting 13-member committee put out the call for designs for a public workers memorial. Among those who jumped at the opportunity in late 2010 was Kelsie Lee, a senior at Colby Sawyer College at the time, whose father Richard Lee is Public Works Director in New London, New Hampshire.

The graphics arts major’s entry was selected as the winner of the $1,200 scholarship from the NH Road Agents Association. One committee member called her submission “far and away the best design.”

“It definitely helped that I had grown up watching what my father did for work. It’s not as easy as some people think. I know what it’s like to have the phone ring at two, three or four o’clock in the morning.”

Adding to the personal connection for Kelsie Lee was the memory of Ryan Haynes, a friend who worked for the Town of New London. Ryan was killed in 2005 when he was struck by a car while he patching potholes on a local street.

While preparing her entry, Kelsie kept jotting down her thoughts and design ideas in a sketchbook. On the night before it was due, she was finalizing a watercolor design, when she suddenly tore it up. “By 2:00 am I had drawn another design that was about 70 percent different from the previous one,” Kelsie remembers.

The new design proved to be a winner that captured the essence of what the committee was looking for. A walkway and reflection garden are surrounded by four gray granite benches that represent the four seasons that public works employees are on-call. Four large black granite monuments will bear the names of those who died performing their duties, and a black granite sign will welcome visitors. A line of 24 inverted shovels will represent every hour of the day that a public works employee will be called to duty.

Surrounding trees to add some height will include a grove of purple lilacs, the state flower.

“I researched New Hampshire plants and flowers, both annuals and perennials, which can stand up to tough weather conditions.” Kelsie says. “I thought a lot about colors and how they will interact with each other, with something always in bloom. The shovels are a tangible thing that everyone can relate to, and a tool that all public works employees may use.”

“It’s phenomenal,” says Carl Quiram. “What’s so impressive is that there are no trivial details. Every aspect of the memorial design means something.”

Since her design was chosen, Kelsie Lee has been working with a Portsmouth environmental engineering firm (Weston & Sampson) on the site plan, which has addressed drainage for the project and fitted the design to its future location on a section of land at the NH Department of Transportation headquarters on Hazen Drive in Concord.

The project is now in the fundraising stage with $300,000 needed in financial and/or services donations to make the memorial a reality. Names of deceased New Hampshire public works employees are also being solicited for review by the committee to determine eligibility for being honored at the memorial.

If at all possible, those behind the memorial would love for construction to begin in the spring of 2013. That can only happen if supporters of this noble idea step forward to help with contributions.

Those whose lives have been most impacted by the death of a loved one in public service are looking forward to its completion.
“It will be a nice recognition of the effort put forward by public works employees and their families,” says Mark Richardson, who has spent his career at the NH Department of Transportation and now heads up the Bridge Design Bureau. “They are called out at all hours in all kinds of weather and are just expected to go.”

Jim Rivers is also looking forward to the new public workers memorial as a place for reflection. While working at the University of New Hampshire, he says he would often eat his lunch at the now closed General Sullivan Bridge where his father died more than 50 years ago. “It was very peaceful.”

**To donate**

The Memorial Committee is accepting both in-kind and monetary donations. Tax deductible donations may be sent to: The Public Works Memorial Fund, c/o Bill Janelle, Commissioner’s Office, NH Department of Transportation, PO Box 483, Concord NH 03302-0483. More information, including the application for submitting a name to the committee for consideration for the memorial, can be found at the following link: [http://www.nh.gov/dot/org/operations/highwaymaintenance/memorial.htm](http://www.nh.gov/dot/org/operations/highwaymaintenance/memorial.htm)

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**National Public Works Week**

**May 19-25, 2013**

The Technology Transfer Center encourages communities to take this week as an opportunity to reach out to the public to remind them how important Public Works is to their daily lives. For more information and ideas for public outreach, check out [www.apwa.net/discover/national-public-works-week](http://www.apwa.net/discover/national-public-works-week)
New Hampshire Public Works Mutual Aid

With record storms, flooding, and most recently Hurricane Irene and the October Noreaster, the need for mutual aid is ever increasing. In times of crisis, a mutual aid agreement allows neighboring communities to provide assistance in the form of labor and equipment to help each other through the disaster. Mutual aid is a FEMA-approved contract and will make the assisting municipality eligible for federal reimbursement.

Mutual Aid is available for only $25 per year and the benefits are innumerable. For more information, visit the T² website at www.t2.unh.edu/ma or contact Beth Hamilton at 603-862-1362.

Visit the UNH T² website today!

www.t2.unh.edu

• Access to the most up-to-date calendar
• Register for workshops online
• Access to NH Road Salt Database
• See important announcements
• Access to the UNH T² Facebook page

NH LTAP is on Facebook & Twitter!

Want to stay informed of our activities? Want to connect with other professionals who attend our training? Want to look at pictures from our training classes and other events? Then “like” us on Facebook or “follow” us on Twitter to stay connected! We are posting information daily on our activities, new programs, training, local news, and services.

www.facebook.com/nhltap
www.twitter.com/nhltap

Retroreflectometer Loan Program

NH LTAP has three retroreflectometers available to rent to NH municipalities. The retroreflectometers are able to accurately measure the retroreflectivity of road signs from a distance. Use one to meet the MUTCD Retroreflectivity Standards by loaning one today!

The fee for the equipment loan is $25, and municipalities may keep the retroreflectometer for up to six weeks (additional time may be requested).

For more information
www.t2.unh.edu/retroreflectometer
t2.center@unh.edu
603-862-2826

Dates
4/3-4/4 Northeast Transportation Safety Conference, Concord
4/11 ACEC/NHDOT Technical Conference, Concord
4/15-4/19 National Work Zone Awareness Week
5/20-5/24 National Public Works Week
5/23 Mountain of Demonstrations, Gunstock
6/12 Master Roads Scholar Luncheon, Manchester

Employment Opportunities
Please see the NH Local Government Center’s website for recent postings for employment opportunities in municipalities across the state.
www.nhlgc.org/classifieds/employment_municipal.asp
Crossword Puzzle

Be the first to complete this crossword and fax it (603-862-0620) to win a FREE T^2 workshop!

NAME

AFFILIATION

E-MAIL

PHONE

ACROSS

2. The most common type of rebar in production today
5. The second construction material for the NHDOT ED competition was?
7. What was the total number of exhibits at NHCCD?
10. What type of coating is used to coat the fiber glass?
11. Concrete is strong in compression, what is it weak in?

DOWN

1. New Hampshire ____ Career Days
3. How many pieces of heavy equipment were there?
4. The town with the CFRP case study bridge.
6. NHDOT’s Engineering Department used uncooked what?
# Spring 2013 Training Calendar

Fall dates to be announced starting mid May!

Check out our website for the most up-to-date calendar
[www.t2.unh.edu/training-calendar](http://www.t2.unh.edu/training-calendar)

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