Transforming the Future of Repair and Retrofit of Pipelines with FRP

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Nearly two decades have gone by since this author presented his idea for strengthening of concrete beams with external bonding of fiber reinforced polymer (FRP) laminates in an ACI publication.

The high-tensile strength, light weight, durability and versatility of FRPs have made these products the material of choice for many repair and rehabilitation projects. To date, numerous bridges, buildings, pipelines, etc. have been retrofitted with these products worldwide. With the publication of design guidelines (ACI 440-08), it is fair to say that FRP is no longer an experimental product but rather a relatively well-accepted construction material.

The forms of FRP products that have been used in retrofit applications to date can be categorized into fabrics and pre-cured laminates. Fabrics offer the widest versatility in the field and are installed with what is commonly referred to as the wet lay-up method. This technique requires properly trained technicians to prepare the resin in the field, saturate the fabric and apply it to the structural member. Care must be taken to ensure the fibers are aligned in proper directions and to remove all air bubbles before the fabric is cured.

Pre-cured laminates allow easier field installation because the saturation of fibers mentioned above is carried out in a plant. They are available in the shape of reinforcing rods or tendons, as well as narrow unidirectional laminate strips that are typically produced in the range of 3 to 4 in. wide and 0.05 in. thick. In the field, these laminate strips are bonded to the exterior surface of the structural element using epoxy putty. A variation of this approach, known as Near Surface Mounted (NSM), embeds the laminate strips or rods into narrow grooves that are cut in the structural member.

While the laminate strips offer ease of installation and higher strength than the wet lay-up system, their use has been relatively limited for the following three reasons: a) the unidirectional reinforcement in these laminates makes them primarily suitable only for flexural reinforcement of beams; and slabs, with some applications for shear strengthening of beams; b) the stiffness of the laminates does not allow them to be coiled into a circle smaller than approximately 30 in. in diameter, and; c) their relatively narrow width is a hindrance in many applications.

The current equipment and technique used to manufacture these laminate strips does not lend itself to making products that are appreciably different. Even with modification of current equipment, one can only produce unidirectional laminate strips that are no wider than approximately 10 in. Overcoming the above shortcomings in laminate strips is not a trivial matter. In fact, some contractors tried to use 10-in. wide laminate strips in repair of pipelines and abandoned the idea after unsuccessful attempts.

This paper discusses the development and many uses of super laminates. As such, it is a landmark advance in the field of FRP.

Super Laminates

Super laminates are a frog leap development in FRP products since the introduction of FRP in construction industry some 20 years ago. They overcome the shortcomings of the above-mentioned laminate strips. These products make possible many applications that have challenged the construction industry for decades. In some cases, the solutions have not been possible without the development of super laminates.

Super laminates are constructed with specially-designed equipment. Sheets of carbon or glass fabric up to 60 in. wide are saturated with resin and passed through a press that applies uniform heat and pressure to produce the laminates. Super laminates offer three major advantages over conventional laminate strips:

1. By combining unidirectional and/or biaxial fabrics, the laminates offer strength in both longitudinal and transverse directions. This tremendous advantage opens the door to many new applications.
2. They are much thinner than conventional laminates. With a typical thickness of 0.025 in., they can fit into a cylinder with a diameter as small as 8 in.
3. The number and design of the layers of fabrics can be adjusted to produce an endless array of products that can significantly save construction time and money.

Super laminates and their flexibility allows them to be bent by hand. They are produced under ISO-9000 certification that ensures highest standards of quality control. This eliminates much of the reliance that has been placed in the past on the construction crew to produce the FRP in the field using the wet lay-up system. For example, when the rolls of super laminates are delivered to a construction site, samples can be tested before the material is installed. In contrast, in the wet lay-up application, field-prepared

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samples are made daily and tested at a later date, at which time repair of defective installations cannot be easily corrected.

Strengthening of Large-Diameter Pipes

More than 6 billion gals of water are lost daily due to leaking pipes, according to ASCE. Additionally, a large number of pipes in water distribution networks and oil and power industries are badly deteriorated and require repair or strengthening. These pipes are usually pressurized and deterioration of reinforcement results in the hoop stresses to exceed the capacity of the pipe. When unattended, the consequences of such failures are grave and can leave entire neighborhoods under water or force emergency shutdown of plants. A common strengthening approach in the last decade has been to apply one or more layers of carbon fabric inside the pipe. The fabrics provide adequate strength in the hoop and longitudinal directions.

Super laminates significantly reduce the construction time. The flexibility of the laminates allows them to be wrapped around cores that are 12 in. in diameter for ease of transport into pipes through manholes that are typically 24 in. in diameter. The ability of super laminates to conform to the diameter of the pipe is a major time- and money-saving attribute of this system for contractors. Most of the current products on the market that can be used as liners to repair or strengthen pipes have a fixed diameter and cannot be applied to different size pipes.

Installation involves applying a thin layer of epoxy putty to the back of the super laminate and pressing the laminate against the pipe surface. No effort is required to remove the air bubbles as the super laminates are pre-cured. Depending on the diameter of the pipe, the elastic memory of the coiled super laminate may cause it to expand inside the pipe and snap against the host pipe with little effort. Continuity of the super laminate rings is achieved by adequate overlap lengths in the hoop and longitudinal directions. Thus super laminates do allow strengthening of the pipe in both hoop and longitudinal directions with a single application.

Not only are super laminates installed faster than fabrics, it is possible to include multiple layers of fabric into a single laminate, further reducing construction time. When steel pipes require strengthening to avoid galvanic corrosion, a layer of glass fabric is typically applied to the surface of the pipe before any carbon fabric is applied. This protective layer can also be included in the super laminate. Thus instead of saturating and applying three layers of fabric to the pipe, the strengthening can be achieved by installing a single layer of super laminate. This can reduce the construction time by as much as 80 percent in many jobs. Such significant reduction in repair time makes many larger retrofit projects possible.

Repair of Small-Diameter Pipes

If the diameter of the pipe is small and human entry is not possible, the pipe can be repaired using a packer. Packers

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are cylindrical shaped frames that house a closed bladder on the outer surface. An appropriate length of super laminate can be cut and coated with epoxy putty; the laminate is then wrapped around the packer and is held in that position with the aid of strings. The assembly is lowered into the pipe through access ports and it is pulled to the desired location with the help of closed-circuit TV cameras. The packer is then inflated allowing the super laminate to adhere to the host pipe; after a few minutes, the packer is deflated and removed from the pipe.

Additional pieces can be similarly installed with a small overlapping length to repair or strengthen a larger length of the pipe.

A major cost associated with pipeline repairs is the traffic control required due to bypass pipes that are laid at the street level. Most repair systems require inserting a flexible pipe or liner between adjacent manholes and curing it using steam or hot water. All such systems require the repair area between the manholes to be clear of any obstacles. Therefore, using plugs at ends, water or sewer is pumped to the ground level to bypass the repair area.

In contrast, repairs with super laminates do not have this restriction. Using flow-through packers, a smaller diameter flexible hose or pipe can be used to bypass the fluids inside the pipe. The super laminate can be applied on a third flow-through packer that rides on top of the flexible hose and can deliver the repair materials to the damaged area.

Mo Ehsani *founded QuakeWrap Inc., a company offering turnkey solutions for repair and retrofit of structures with FRP products.*

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