Composite Material Shields Wires and Workers During Electrical Repairs

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Beneath the feet of the population who depends on it, electricity travels to homes and businesses through bundles of subterranean wires. These vital bundles are buried in concrete casings that protect the wires from the underground environment.

But the casings also put at risk the repairmen responsible for the repair and maintenance of underground electrical cable and wire. Before they can fix an electrical problem, repairmen must first break through the protective layer of concrete surrounding the wires. In the process, however, they are exposed to the risk of damaging the wires and electrocuting themselves.

Seeking to protect both wires and workers, a prominent electric company decided to equip their repairmen with special shielding channels designed to be slipped over electric wires during the process of breaking through concrete casings. In designing these channels, a key decision was the choice of material. A demanding set of requirements eliminated common materials such as metals and thermoplastics from consideration. But the designers of the shielding channels found exactly what they needed in a thermoset composite material, which offered a winning combination of properties at an attractive price.

Shielding Considerations

Electrical wire repairmen use sledgehammers and jackhammers to break the concrete around electric wires. Obviously, these implements and the force they bring to bear can damage the wires themselves if contact is made with them. In addition, contact with the electric wires could mean severe shock or even electrocution for the workers wielding the hammers. So the material used to make the wire shielding must be strong enough to prevent the enormous forces produced by the hammer from shattering or puncturing the shielding units.

For applications like this, many materials engineers would probably start by considering a relatively inexpensive thermoplastic option, such as an extruded high-impact polystyrene. But this material wouldn't be strong enough to withstand jackhammer impacts unless the shielding unit had a wall so thick that it was difficult if not impossible to use. For example, a unit made of 1-inch-thick polystyrene might provide adequate impact resistance, but it would be too thick to squeeze into many concrete conduits, where wires take up as much as 70 percent of the available space.

Another problem with thermoplastics in general is that they can be either ductile or brittle, which often forces designers to choose between impact and puncture resistance. Ductile thermoplastics won't shatter when impacted, but they tend to have very low puncture resistance. On the other hand, brittle thermoplastics offer much better puncture resistance, but they may shatter when subjected to high impact loads. Neither of these options would protect the shielding units, which must stand up to both high impact and high puncture forces produced by sledgehammers and jackhammers. If a jackhammer had punctured a thermoplastic-based coating in the field, the conductive metal would again have been exposed, endangering the lives of workers in contact with the shielding unit.

Metal Downsides

Unlike most thermoplastics, metals have more than enough strength for the job. On the downside, though, metals are heavier than thermoplastics, which could create handling difficulties in the field. Even though the largest of the shielding units is only 18 inches long, a steel version of the unit would weight about 16 pounds. If a repairman was required to slide four of these units into place, one behind the other, in order to break open a large area of concrete conduit, the worker would end up trying to push 64 pounds of steel along the wires when inserting the final unit into the conduit. In addition to the physical difficulties of such a job, the worker could end up damaging the wires while trying to shove or hammer several heavy metal shielding units into a tightly packed conduit.

Another consideration is the weight added to repair trucks carrying the units. A truck carrying 12-16 steel shielding units would carry an extra couple of hundred pounds on a permanent basis.

To mitigate these weight-related problems, the shielding units could be made of a lighter metal such as aluminum. But metals of any type would present other serious problems in this application. For example, metals can be permanently deformed by high impact loads. So after a short time absorbing impacts from sledgehammers and jackhammers, metal shielding units would probably be scarred by a large number of permanent dents.

Since wire insulation is much softer than metal, the metal shielding unit can act like a razor blade, shaving insulation off wires as a worker slides the unit into place. So during the course of a job to repair one wire, workers could shave the insulation off of another. To make matters worse, this damage probably won't be seen by the workers who cause it, so it will require yet another repair job at a later date.

Troublesome as these issues are, the most serious problem for metals in this case is their electrical conductivity. Workers who place a conductive metal shielding unit onto a damaged electrical wire are placing their lives in danger. Of course, metal parts can be coated to neutralize their conductivity. But if the electric company had chosen this course, lives would have depended on the condition of a coating.

A Better Option

With thermoplastics and metals failing to meet key application requirements, another material is required: thermoset composite. Composite materials consist of fiber reinforcement in a polymer resin. The fiber provides strength and stiffness, while the resin protects the fibers and gives the material its shape.

Composite resins start out as liquid polymers, but they are changed to solids during the prepregging and molding process. Exposure to thermal energy causes the formation of three-dimensional covalent bonds between polymer molecules. This process, known as crosslinking, is irreversible.

Since crosslinking permanently solidifies the materials, they are known as thermosets. Crosslinking creates a rigid molecular structure that allows thermosets to maintain good physical and electrical properties. Most thermoset resins are polyester, vinyl ester, or epoxy. As for reinforcement, many types of glass fiber can be used in thermosets, depending on the product's strength requirements.

The composite choice for the shielding units is off-the-shelf glass-epoxy convolute tubing. The reinforcement in this material is E-glass, a low-alkali borosilicate glass with good electrical and mechanical properties. E-glass is not as strong as a structural glass reinforcement option called S-glass. But it provides the necessary strength and other properties for the application—and at a cost that is 50-75 percent less than that of using S-glass. In the composite tubing chosen for the application, E-glass comes in the form of a woven substrate. Featuring a so-called "even weave," the glass provides reinforcement to handle force in any direction it is applied by hammer-wielding electrical wire repairmen.

Thermoset Benefits

Providing high strength and rigidity, the thermoset tubing features a flexural modulus as much as 10 times greater than that of many common thermoplastics. Though not as strong as steel, a shielding unit made of the composite tubing weighs only about a quarter as much as one of the same size made of steel. Even aluminum is twice as heavy as the thermoset, while only providing roughly the same amount of impact and puncture resistance. In addition to high strength, the thermoset tubing provides excellent electrical insulation. This is due to the high resistivity
of E-glass and the good insulation properties of epoxy resins.

Unlike metals, the thermoset material will not permanently deform on impact from hammers. Instead, it temporariliy deforms and then springs back to its original shape. In addition, the thermoset is much less abrasive than metals. Since the hardness of the resin is about the same as that of the wire insulating material, the thermoset shielding units can slide back and forth along electrical wires hundreds or even thousands of times without damaging the insulation.

The thermoset material is also durable. Sitting in the back of repair trucks, thermoset shielding units will last for years, if not decades. By contrast, units made of carbon steel would experience constant rusting problems if exposed to the elements for years. Using stainless steel would prevent rusting, but the thermoset provides a much better cost alternative, in addition to preventing rust.

As for thermoplastics, low-end versions become brittle when exposed to sunlight. Thermoplastic shielding units could be protected from the elements inside storage boxes in the back of repair trucks. But in these boxes, they would likely come in contact with moisture, greases, and oils that can degrade low-end thermoplastics.

Besides its advantages in the field, the thermoset composite is fairly easy to manufacture into the required shapes using common tools. In a machine shop, 3- to 4-inch-diameter composite tubes with 1/4- and 1/2-inch wall thicknesses are cut in half in the lengthwise direction to produce channel shapes.

Currently, thermoset shielding channels have been in use for about a year. Workers slip the units over electric wires after creating a small opening in the concrete casing. If it is a tight fit inside the casing, workers can use the 1/4-inch-thick channels. If there is more room in the casing, they can use the 1/2-inch-thick units to provide extra protection for themselves and the wires.

Once one channel is in the concrete conduit, more can be slipped into the opening behind it. This way, protective channels can be pushed up the line as far as is necessary to cover the area where concrete will be broken. When the job is finished, the channels are removed and stored in the repair truck for use on the next job.

Conclusion

In a variety of industries, more designers are finding that thermoset composites compare favorably to metal and thermoplastic alternatives. In some cases, thermosets meet a number of different requirements that cannot be met by conventional materials. In cities that employ thermoset protection, electrical workers and wires are both safer thanks to a combination of benefits that could only be provided by the highly capable class of materials known as thermoset composites.