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A worker prepares a reinforcing bar cage for the AirportLink extension of the Miami-Dade Transit Metrorail system. To enhance electrical isolation of the system's electrified rails, glass-fiber-reinforced polymer reinforcing (GFRP) bars were used in pads and pedestals supporting the rails. For more on the AirportLink project and how GFRP bars were used in its construction, see "Ensuring Electrical Isolation in Elevated Rail," starting on p. 22. *(Photo courtesy of Hughes Brothers Inc., Seward, NE.)*

departments

IN Ci

February 2012

The basic framework of any system—whether it's for transportation, communication, security, water supply or sanitation—must be maintained. If not, economic vigor, social structures, and the environment will be damaged. Sound familiar? Yes, infrastructure maintenance is a key part of sustainable development.

But maintenance is often considered a necessary evil. Consider the example of repairing a bridge on a major thoroughfare. Besides the cost, the mere act of making the repair can create traffic congestion and delays. Delays are externalized costs—a transportation department doesn't have to pay drivers for their lost time—but they are still costs. Do it cost effectively and fast—that's the core of our article on bridge deck overlays (p. 31)

Perhaps the best way to have cost effective and fast maintenance, however, is avoiding it in the first place. Electric transit systems are wonderful features for any city, but neighboring water supply and sanitation systems and the transit systems themselves can be damaged if electric current strays from the rails and takes an alternate path to the traction power substation. Insulating rail seat pads, rail clips, and embedded anchors are essential system features that can help avoid stray currents. Providing additional insulation using glass-fiber-reinforced polymer reinforcing bars adds to the security, minimizing the occurrences of stray current corrosion. Avoiding the need for maintenance—that's the core of our cover article on the most recent addition to the Miami-Dade Transit Metrorail (p. 22).

Because infrastructure is so essential, it's no wonder that companies and engineers compete to provide the best solutions to maintenance issues. And, it's why we'll continue to report on those solutions in future issues.

Rex C. Donahey

Ensuring Electrical Isolation in Elevated Rail

GFRP reinforcing bars tie rail plinths and pedestals to Miami Metrorail guideway girders

by Doug Gremel

The Miami-Dade Transit (MDT) Metrorail is a 22 mile (35 km) rapid transit system serving metropolitan Miami, FL. The system will soon be greatly enhanced by the addition of the 2.4 mile (3.9 km) AirportLink, connecting the existing Earlington Heights Station to the new Miami Intermodal Center (MIC). Developed by the Florida Department of Transportation, the MIC is a major transportation hub that serves as a central transfer point to different modes of transportation, including Metrorail, Metrobus, Tri-Rail, Amtrak, intercity buses, tour buses, taxi cabs, rental cars, and the Automated People Mover (APM) connection to the Miami International Airport. Construction of the AirportLink and MIC projects began in the spring of 2009 and will be completed in the spring of 2012.

Cutting the Current

Within the Metrorail system, power is supplied to the transit vehicles via a contact (third) rail (Fig. 1), and the running rails for the transit vehicle serve as the negative return to the power substation. As for any electric transit system, stray current corrosion is a major concern. This is typically handled by insulating rail fastener anchor inserts and creating an electrically continuous network of reinforcing bars in the plinths, pedestals, and deck supporting the rails.[1]

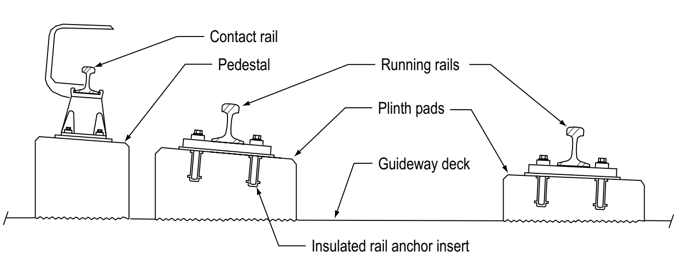

Fig. 1: Schematic of the rail system. Power is supplied to transit cars via the contact rail. The running rails support the transit cars and provide the return circuit to the power substation

In existing elevated sections of the Metrorail system, steel reinforcing bars were used to connect cast-in-place pedestals and plinth pads to guideway girder decks. The electrically continuous network was established by welding longitudinal bar splices and welding longitudinal bars to transverse collector bars. Experience has shown that the clearance between the plinth pad reinforcing bars and the insulated rail anchor inserts can be very small, however, so damage to insert insulation can cause electrical shorts. To address this issue in the construction of the elevated rail from the Earlington Heights Station to the MIC as well as in the MIC crossover areas of the AirportLink, electrical isolation was enhanced by using glass-fiber-reinforced polymer (GFRP) reinforcing bars to make the structural connections between guideway structures and cast-in-place pedestals and plinth pads.

Construction Detailing

Three types of guideway structures were used for the AirportLink.[2] Thirty in. (760 mm) deep cast-in-place slab bridges were used at the AirportLink connection to the Earlington Heights Station. AirportLink sections over existing rail, existing and planned highways, and the Miami River were constructed by launching precast segmental box girders from piers (balanced cantilever construction). Where crane access and maximum span allowed, guideway structures consisted of 72 in. (1830 mm) deep precast concrete U-beams that were raised into position and then completed with a cast-in-place deck. To provide the structural connections between the guideway structures and cast-in-place rail plinths, No. 3 (10 mm) GFRP stirrups extended above the precast decks of the box girders (Fig. 2). Similarly, No. 4 (13 mm) GFRP stirrups extended above the cast-in-place decks.

The adage, the "devil is in the details" is certainly true for reinforcing bar detailing. To ensure the rail cars were stable along curves, the yaw of the rail and elevations of the pedestals and plinths had to be varied (Fig. 1). Initial design detailing of the GFRP bars followed detailing conventions that would traditionally be used for steel bars. That is, to accommodate variation in the height of the rail along the length of the track, the detailer assumed that it would be possible to bend and modify the reinforcing bars in the field, as is traditionally done with steel reinforcing bars. However, although GFRP bars can be supplied with bends, they must be fabricated according to a firm bar schedule—the bends must be fabricated at the time the bars are produced. A key solution was to adopt a minimum acceptable embedment depth from the deck into the rail plinth and shift any variations in the reinforcing detailing from the deck bars into the plinth bars. While this shifted reinforcing from the deck to the plinths, it allowed for field adjustments to accommodate the variations in yaw and elevation.

With a fixed number of stirrups and a fixed depth of embedment into the plinths, the segmental precast contractor and the cast-in-place contractor were free to focus on locating the proper quantities of stirrups along the rail centerlines. Responsibility for adjustments to the final heights of the plinth reinforcing bars was shifted to the trackwork contractor, the contractor that was also responsible for precisely setting the rail height (Fig. 3).

To aid each of the contractors and ensure economical fabrication of the GFRP stirrups, the number of bar configurations was minimized. To assist the trackwork contractor, plinth length, width, and height were distilled into six combinations, each with its own kit of bent GFRP bars (Fig. 4). The logistics of getting the right bar to the right location along the entire length of the 2.4 mile (3.9 km) guideway structure was thereby simplified, helping to minimize installation errors.

Uniquely Constructible

Fiber-reinforced polymer (FRP) bars are unique in that they can be easily field cut with fine blade saws or

Fig. 2: The segmental precast deck elements included post-tensioning ducts, steel reinforcing bars, and GFRP stirrups. The GFRP bars were detailed to extend above the finished deck

Fig. 3: The trackwork contractor was responsible for installing the plinth reinforcing, setting the rails, and placing the concrete within plinths and pedestals. Here, workers are positioning rail anchors and assembling plinth forms. The GFRP plinth reinforcing and insulated rail anchor inserts can be seen below the rails

grinders equipped with carborundum blades. The trackwork contractor took advantage of this feature by prefabricating plinth cages, positioning them along the rail path, and field trimming the legs of the cage to adjust the heights of each leg (Fig. 4 and 5). Although individual bar locations had to be tweaked to avoid deck bars and embedded rail track inserts (Fig. 6), this was simply a matter of removing bar ties, repositioning bars, and installing new ties.

Fig. 4: GFRP bar kits comprised hooked and straight bars for the trackwork contractor to assemble into plinth cages as required

Fig. 5: A worker prepares to trim the legs of a plinth cage to set the correct height before installing it over the projections of the plinth stirrups (to his left). To the worker's right, bar cages have been installed over the stirrups in the guideway deck

Some extraordinary circumstances also arose during the course of construction, requiring some key workarounds with the GFRP bars. During launching of the precast concrete segments, for example, it was necessary for large gantry cranes to be positioned directly above the GFRP bar locations (Fig. 7). This meant that GFRP bars in those locations that bore the crane reactions could be crushed (or were removed).

The workaround was to install replacement bars using epoxy adhesive. A series of anchor pullout tests established that GFRP bars could be developed using adhesive. Because it's much easier to drill down the embedded shaft of a GFRP bar than through concrete, it became common practice to simply trim off a damaged GFRP bar, drill directly into the remaining portion of the remaining segment of the bar to a prescribed depth, clean the hole, install the adhesive, and push a new bar into the hole. The same procedure was used to replace bars damaged during the normal course of construction (Fig. 8).

The trackwork contractor was able to set up jigs and fixtures to mass-produce rail plinth cages and then simply place them along the length of the track for height adjustment. For tying the GFRP bars for the prefabricated cages,

Fig. 6: Plinth stirrups, cages, and rail fastener anchor inserts (blue) prior to concrete placement

Fig. 7: Gantry cranes and other equipment sometimes conflicted with GFRP bars. Here, the bars at a reaction point for a crane girder have been trimmed flush with the deck. They will be replaced before completion of the rail plinth

the specification instructed the trackwork contractor to use plastic-coated wire ties, but the contractor eventually adopted injection-molded polymer bar clips dispensed from a gun-type fixture (Fig. 4 and 5). Although the clips were more expensive than wire ties, the increase in productivity more than made up for the added cost.

A Steep Learning Curve

As with any project that incorporates a relatively new product or process, there is initial skepticism. But, the doubt dissipates once experience is gained. For the Metrorail project, the GFRP bars were the new product, but workers quickly learned to take advantage of the easy handling of prefabricated cages made possible by the light weight of GFRP. Working with the GFRP reinforcing bar supplier Hughes Brothers, Inc., the general contractor Odebrecht-Tower Community Joint Venture; the segmental precast contractor Rizzani de Eccher USA, Inc.; the cast-in-place deck contractor Baker Concrete Construction; and the trackwork contractor Railworks Track Systems, Inc., quickly agreed on how to stock and handle the GFRP bar kits they were responsible for installing.

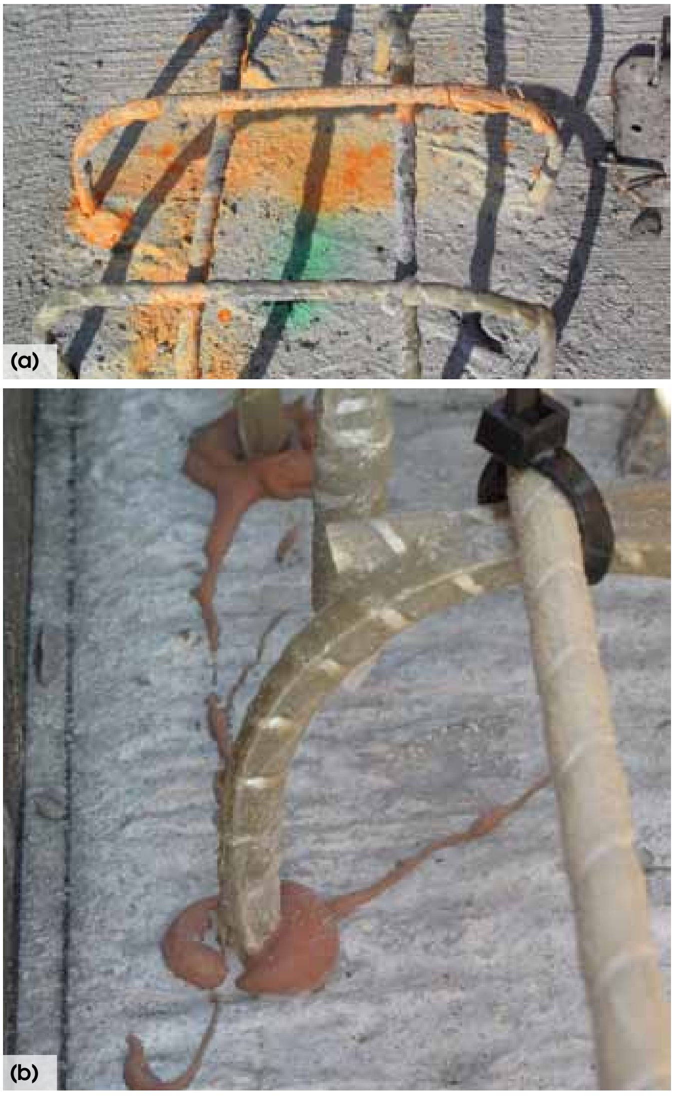

Fig. 8: If damaged, GFRP bars could be replaced with new bars anchored using epoxy adhesive: (a) damaged bars have been marked for replacement; and (b) after the existing bars were cut off, new bars were installed in holes drilled through the existing bar

Of course, there were the occasional unforeseen conditions that made it necessary to “borrow” bars from other parts of the project. Fortunately, there was good communication and coordination by all parties and willingness to buffer suitable quantities of fabricated GFRP bars as they were shipped from the bar manufacturer in Nebraska to the job site in Miami, FL.

The project is one of the largest uses of FRPs in civil infrastructure to date. As of publication, all indications are that the implementation of GFRP bars in this major public works project will be a complete success. While this is not the first implementation of GFRP bar for electrical isolation in high-voltage rail lines, it certainly will not be the last.

Acknowledgments

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Selected for reader interest by the editors.

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