Culver Line Viaduct Rehabilitation

Brooklyn, NY

Submitted by Sika Corporation

Culver Line Viaduct after concrete repairs

The New York City Subway system is the largest rapid transit system in the world. It runs 24 hours per day, 365 days per year, and serves over 1.7 billion riders each year. The Culver Line first opened in 1919. The Culver Line Viaduct was built in 1933, high above the Gowanus Canal to allow tall-mast ships to pass below. In fact, the Smith-Ninth Street stop, at an elevation of 87.5 ft (26.7 m), is the highest aboveground subway station in the world.

The Viaduct is primarily supported by a series of concrete-encased steel bents. It is approximately 1 mile (1.6 km) in length. The structure supports four tracks, two subway lines, and two stations. The landmarked structure currently serves close to 90,000 "straphangers" each day.

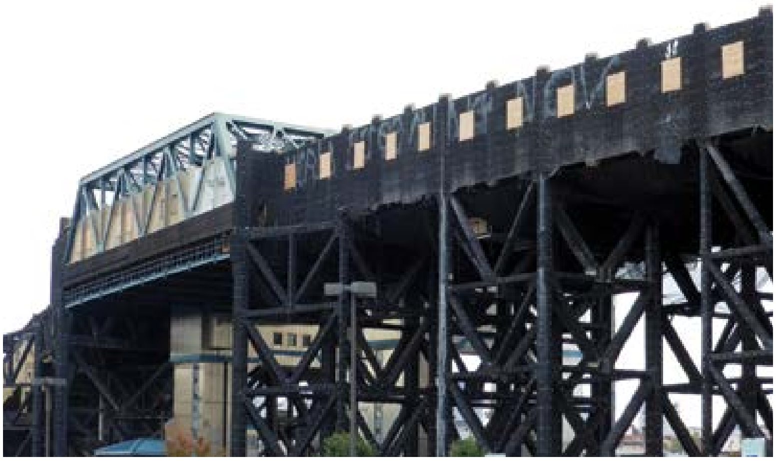
CONCRETE DETERIORATION

After many years of service, the Culver Line Viaduct was showing its age. Because there was no existing waterproofing membrane, water infiltration was a serious problem. As the water penetrated the concrete, it caused significant corrosion damage to the reinforcing steel and the underlying steel members encased in concrete. This led to cracking, spalling, and, ultimately, pieces of concrete coming loose from the structure. To protect the public from falling debris, in 2003, as a stopgap measure, the entire viaduct was covered with a black mesh and netting system pinned to the trusses to catch and contain the loose concrete. Due to budget constraints, this "temporary" solution of the black netting stayed in place for nearly a decade.

Finally, the City decided to repair this project with an extensive top-to-bottom approach to successfully address the root cause of the issue (water damage) while conducting structural repairs below. In addition, a new low-vibration track was installed with new track drains and a new waterproofing membrane. On the underside, wide-scale concrete repairs were performed as the black netting was finally removed, which revealed extensive damages to the superstructure. After removing all loose concrete and hand applying new concrete repair mortars in accordance with ICRI Technical Guidelines, over 1 million ft^2 (92,900 m^2) of fiber-reinforced polymer (FRP) fabric was installed to provide confinement to the concrete. The entire surface was then painted with a protective coating to enhance the aesthetics while providing added protection against the environment.

CONCRETE REHABILITATION

To make large-scale concrete repairs on the structure, a tremendous amount of coordination was necessary. The condition of the concrete varied from



Culver Line Viaduct prior to concrete repairs

Installing FRP on the underside of concrete arches off scissor lift

Finished repairs on underside of concrete arches and beams

location to location and was mostly unknown until the black netting was removed. A condition assessment was made one section at a time by the inspectors and the contractor together to determine the extent of the damages and the best method of repair. In many areas, the corrosion damage was so severe that large sections of concrete were chipped out with demolition hammers. In other areas, the existing concrete surface was greater than a CSP-9 and needed to be leveled out with repair mortars to fortify the surface. Most of the spalled concrete was patched with a polymer-modified, hand-applied mortar containing an integral corrosion inhibitor, especially for the overhead repairs. All exposed steel and reinforcing bar was protected with an anti-corrosion coating.

For the larger-scale and full-depth repairs, a polymer-modified, self-consolidating concrete mixture containing a migrating corrosion inhibitor was used. All cracks greater than 10 mils in width were pressure injected with a low-viscosity epoxy resin prior to FRP repairs.

One of the challenges on this project was the complex geometry of all the structural elements comprising the viaduct. The intersection of the deep beams, joists, and arched soffit made the installation of the FRP quite difficult, especially because it was all done overhead. Also, the owner was very concerned about maintaining the breathability of the underlying concrete because, in many areas, the concrete had become quite saturated over the years due to the absence of a waterproofing membrane above. Thus, a survey was performed and the fabrics were custom cut and labeled to meet the unique geometric patterns of the elements. A gap of 2 to 3 in. (51 to 76 mm) was maintained between adjacent sheets of fabric to allow adequate ventilation of the concrete and prevent full encapsulation of the structure.

INSPECTION AND TESTING

The contractor and inspector, along with the material manufacturer, were required to verify their work as it took place. Daily logs were maintained to keep track of the temperature, humidity, site conditions, batch numbers, crew members, and quantities installed. To verify the strength and condition of the substrate, as well as field quality control, a trained field supervisor was required at all times to verify surface preparation, resin mixing, application of repair materials, and protective coatings. Tensile bond testing was conducted at a minimum once every 3000 ft^2 (280 m^2) of repaired area where substrate failure was required, as well as a minimum strength of 200 psi (1.38 MPa). FRP witness panels were prepared and cured in the field in the same manner as actual installation. Independent testing was then conducted to verify the tensile strength, elongation, and modulus of the laminates. In addition, surface moisture readings were conducted along with temperature, relative humidity, and plastic sheet testing to ensure proper bond and long-term performance.

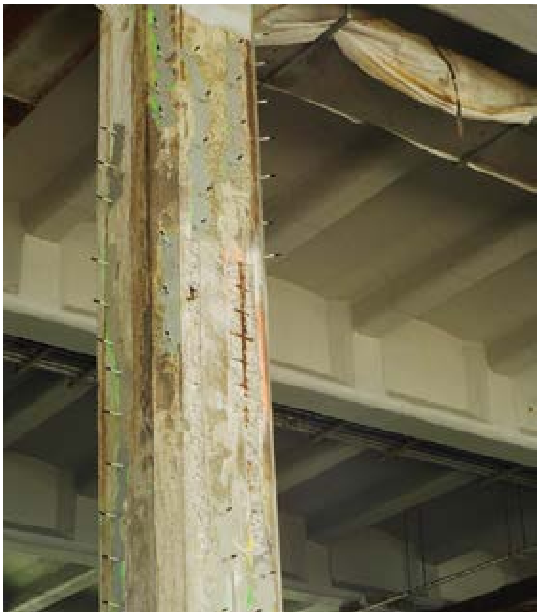
UNFORESEEN CONDITIONS

The biggest challenge to the contractor was the unknown substrate conditions. As the black mesh was tightly installed in 2003 with no subsequent maintenance or repairs since, they had no idea as to the extent of the damages until the netting was removed. In many areas, the corrosion damage was so severe that entire sections of concrete were completely delaminated and large chunks of concrete could be removed by hand. The contractor elected to work in phases so the netting would remain safely in place until they were ready to perform repairs.

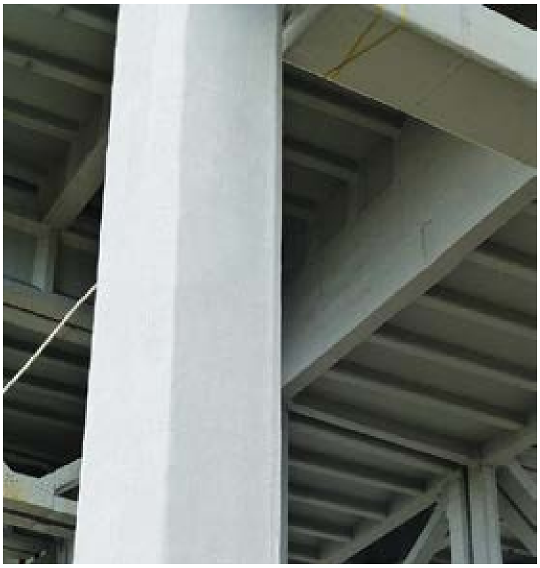
Working in an urban setting on an active subway line presented its own set of unique challenges. In many areas, the work space abutted right up against apartment houses, private homes, and stoops. The contractor had to be sensitive to the community and oftentimes ask for permission to temporarily encroach on private property. The work could not be conducted from above because the F and G trains were never taken out of service during construction, meaning all access was from the bottom.

SPECIAL CHALLENGES

Working on an elevated viaduct on an active subway line in the middle of Brooklyn would present enough obstacles for any contractor. However, no one predicted what would happen in late October 2012. The storm of the century, Hurricane Sandy, struck New York with a vengeance. The entire NYC Subway System was shut down from October 28 until October 30, with many lines being out of service for over a week due to the significant flooding. Wind gusts were recorded at 100 mph (160 kph), 53 New Yorkers lost their lives, 250,000 vehicles were destroyed, and $18 billion in damages were recorded just in New York. Despite this devastation, work on the Culver Line was only shut down for a few days, as the new waterproofing membrane and FRP wraps successfully resisted the hurricane forces. The contractor took the proper precautions to move all equipment to higher grounds and stored up enough gasoline and diesel fuel to resume operations once it was safe. They only lost one generator as a result of the storm and the biggest obstacle was the workers trying to get to work because gasoline was in short supply and the workers also had to attend to their families in the time of crisis. However, the greatest strength of all New Yorkers is their resiliency and once things started returning to normal, it was just another event that made everyone stronger moving forward.



Epoxy injection of cracks on a column



Typical column repair with epoxy injection and FRP wrap

Culver Line Viaduct

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PHASE 2 CONTRACTOR
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