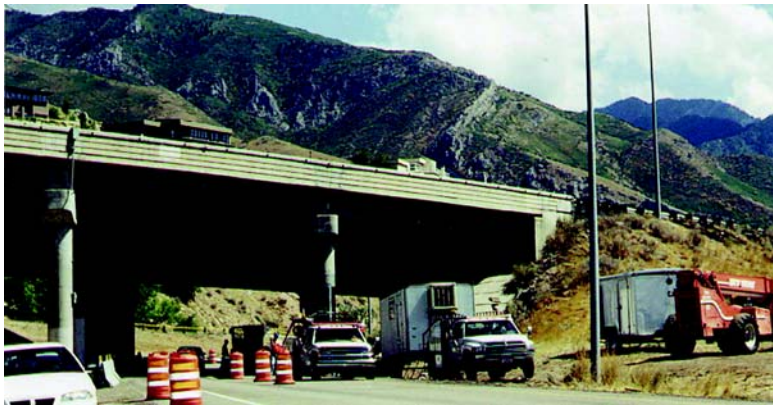
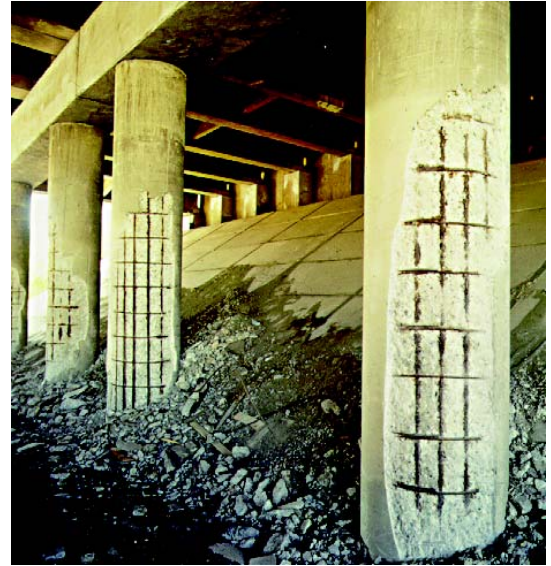


Seismic Upgrade of I-80 Bridges in Salt Lake City using Carbon Fiber Reinforced Polymers

By Scott Isaac and David White, P.E.



I-80 and Foothill Boulevard Bridge



Typical corrosion damage on bridge piers

In the spring of 2000, the Utah Department of Transportation (UDOT) began a massive program to repair and upgrade a number of bridges built during the 1960s in Salt Lake City, including the seismic upgrade of five bridges using carbon fiber reinforced polymers (CFRP). This project was the culmination of several years of extensive research and planning.

One of the objectives of the project was to have all construction completed well before the 2002 Winter Olympic Games. The additional traffic from the Olympics meant that all traffic lanes needed to be kept open to increase flow as well as prevent catastrophe should an earthquake strike at some point. This goal was achieved, as construction was completed in June 2001.

The Need for Seismic Upgrade

Twenty-five badly deteriorated bridges along a five-mile corridor of Interstate 80 in Salt Lake City, Utah, were in need of major repair. Most were showing advanced signs of corrosion due to prolonged exposure to the harsh environment and deicing salts. Of the 25 bridges, 12 were considered to be structurally deficient, which indicated that significant elements of each bridge needed repair. There was a significant amount of spalling concrete from the decks, pedestals, bent caps, and columns. Beams and bearing units were also in

poor condition. Without repairs, many of these bridges might have required weight restrictions, bracing, shoring, or emergency replacement of decks and other components. All of the bridges failed to meet current seismic design standards.¹

Interstate 80 in this part of Salt Lake City crosses over the Wasatch Fault, which runs along the east bench of the valley. Wasatch Fault is one of the longest and most active faults of its type in the world and contributes to the Wasatch Front's designation of having the greatest earthquake risk in the interior of the western United States.² The bridge structures along this section of the freeway were designed and built between 1964 and 1971, prior to the current seismic design codes that are in place today. The violent shaking during an earthquake could collapse a number of these older and underdesigned bridge structures along I-80 between State Street and the mouth of Parley's Canyon, not only crippling the movement of cars and emergency vehicles along the freeway, but also making the surface streets below impassable for rescue and public safety personnel. Since it was not economically feasible to completely rebuild the bridges to current seismic standards, other options were considered. In the end, it was decided to use simple, low-cost techniques, including CFRP fabrics and other structural repairs that could reduce the severity of damage from an earthquake.

UDOT Engineers and expert consultants from the University of Utah discussed and presented new technologies such as CFRP, emphasizing the importance that as much seismic retrofit work as possible should be done. The UDOT expressed its intent to complete as much research as funding would allow (in partnership with the University of Utah) on the rehabilitation techniques and materials to be used for the I-80 project. UDOT hoped to extend the life of these bridges for a minimum of 10 years, at which time they would rebuild this section of freeway with new structures.

The Design Concept, Research, and Testing

In 1998 and 1999, engineers at the University of Utah were presented with the unique opportunity to conduct full-scale, in-situ tests of the CFRP system on bridge bents similar to I-80 that were scheduled for demolition during new freeway construction in another part of the city. Dr. Chris Pantelides, Professor of Civil Engineering at the University of Utah, explained that several concepts and designs on retrofitting older bridges with FRP were tested and evaluated in those tests, including:

1. Restoration of columns for confinement, lap splice control, and shear strengthening;
2. Shear strengthening of the bent cap-column joints; and
3. Tensile anchorage of longitudinal column bars ending in the bent cap.

The test bents were wrapped with CFRP according to the design and then pushed to failure. The retrofitted columns and bent caps deflected 20½ inches before reaching total failure. Dr. Pantelides explained that “all of the design concepts were verified in this testing, and the goal of improving the ductility of the bridge bent caps and columns was achieved.” These proven design ideas were eventually implemented in the State Street and I-80 Bridge projects, which needed flexural strengthening of the bent caps as well as shear reinforcement.

Developing the Specifications and Special Provisions

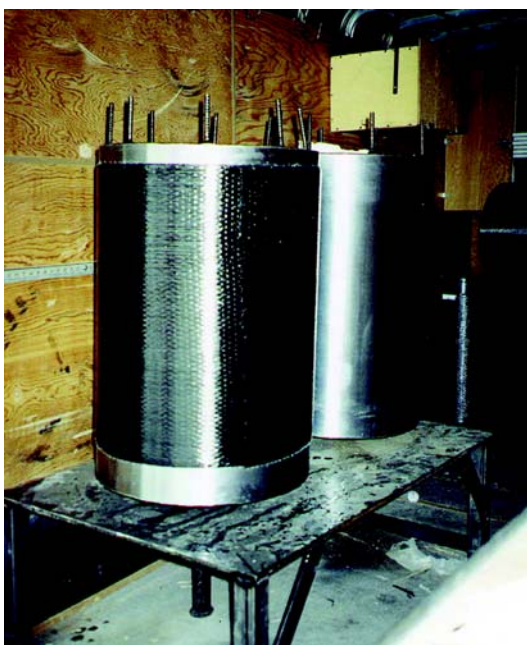
The second part of this research program was the development of the specifications, which were written with input from UDOT, Dr. Pantelides, and outside consultants, who created special provisions for column and bent-cap wrapping. UDOT said that, due to environmental concerns, only CFRP systems would be considered. The composite wrap system was required to meet minimum initial properties for tensile strength, Naval Ordnance Laboratory (NOL) ring strength, fiber volume, and glass transition temperatures. In addition, the special provision called for the required design thickness to be based on an environmental durability-rating



Wrapping bridge pier with carbon fiber fabric



Preparing flat-panel specimens for QC testing



NOL ring specimens for QC testing



Spray application of acrylic coating for UV and abrasion protection



Bridge bent strengthening at State Street overpass

factor, which would account for material property losses due to environmental aging over the projected life of the composite.

Another part of the specification required a great deal of field sampling and testing to ensure quality control on the project. UDOT felt that this testing requirement was more beneficial for quality than the number of previous projects a contractor may have completed. This included flat panel samples, NOL rings, and core samples of the CFRP to verify strengths, stiffness, fiber volume, resin-fiber ratio, thickness and T_g (Glass Transition Temperature). The panels and core samples were tested by an independent laboratory, and the results were sent to both the contractor and UDOT. Michael Fazio, P.E., UDOT Resident Engineer, said that, “the benefit of this testing was an after-the-fact assurance of quality control on the project. The testing was specified in the beginning because the selection of the fiber and resins was unknown, and testing was required to assure quality and uniformity of the product from UDOT’s standpoint.”

Near the beginning of the project, key UDOT engineers were able to visit the manufacturer’s plant in Salt Lake City, where the carbon fiber is produced. Fazio says, “the field-testing was beneficial,” but he feels that “some of the testing was redundant because of the quality assurance that took place by the supplier in the carbon fiber-manufacturing process. A lot of money was spent for testing,” he pointed out, “but it was useful information that helped with the overall research on the project. Concrete has been something we have dealt with for many years; however, the CFRP is relatively new to the civil engineering and construction environment, and we needed to have ways to test these materials to satisfy our goal for a quality project.”

Training and Cooperation

The contractor, the CFRP manufacturer, UDOT, and the Federal Highway Administration conducted a training seminar long before the first layer of CFRP was installed to ensure a smooth project. During the seminar, installation crews, inspectors, quality assurance (QA), quality control (QC), and testing personnel were given training and hands-on experience with the CFRP. This training helped to coordinate the responsibilities of all parties and provided a perspective from the installer’s point of view while focusing on how important QC was going to be. Excellent cooperation on the project was a key benefit of the training seminar and made everyone’s job easier.

Installation and QA/QC Inspection

Five bridges were chosen to receive the CFRP for seismic upgrade. A total of 76 columns and four bent caps (beams) were wrapped. Some columns received as many as 17 layers of CFRP. During the project, 124,000 square feet of fabric and 1,760 gallons of epoxy were used. After weeks of concrete restoration and repair were completed, surface preparation began prior to the installation of the fabric. The bent caps at the State Street location required the most extensive surface preparation and were the most difficult, because of their horizontal surfaces. The Highland Drive Bridge required the most extensive concrete repair prior to application of the CFRP. Traffic control was also a critical part of this project. Because some traffic lanes could only be closed during certain hours of the day, the staging of the work by the contractor was very important.

Using a typical installation crew of 10 workers, the contractor was able to make quick progress on the bridges. Custom-built platforms lifted in place by a forklift allowed the workers 360° access to the columns, eliminating the need for scaffolding and provided savings in both time and cost. The

installation crews were responsible for making the required daily test specimens, which had to be prepared with great care and precision, and keeping detailed logs of the installation process and test samples. Special tools and equipment were needed (such as the custom-made NOL ring forms) to produce the samples and cure and store them before sending them to the laboratory for testing. Approximately 342 flat-panel specimens were prepared during the project, along with several dozen NOL rings and nearly 75 core samples.

The application of fabric was fairly straightforward on the bridge columns, but the bent caps presented a new challenge for the installation crew. Because the bent caps required flexural layers of CFRP on the bottoms, followed by diagonal wrap layers and then circumferential wraps, the crew spent a great deal of time cutting and preparing fabric for the special widths and angles. This part of the installation was further complicated by the fact that the bridge girders were offset from one another. Following the curing and testing of the CFRP, they were coated with a textured acrylic coating for UV and abrasion protection as well as long-term durability.

Not only was field inspection performed by UDOT for quality assurance, but the contractor also had to provide an independent Quality Control Inspector to make daily site visits and prepare reports on the installation process. During construction, two site visits per day were conducted. During these inspections, surface preparation, fabric saturation, application, curing, sample preparation, and coatings were reviewed.

Long-Term Testing

Currently, the State Street Bridge is being monitored by the University of Utah to determine in-situ environmental characteristics of the CFRP composite. This includes both nondestructive and destructive testing. NOL rings (20-inch-diameter cylinders constructed from five layers of CFRP) exposed to the environment are currently being stored at the bridge site and will be tested on an ongoing basis. The data from these tests will provide needed information about the long-term effects of UV exposure, salt water, and freezing-and-thawing cycles on the CFRP. Flat panels plus CFRP-wrapped concrete cylinders and beams will be tested for tensile, direct pull-off, flexural, and axial compression strengths as part of this study.

Successful Project

The installation of the lightweight, noncorrosive, high-strength CFRP allowed UDOT to seismically upgrade older bridges for a lot fewer tax-paying dollars than building new bridges, especially if the bridges should be damaged by a seismic event. Full-scale testing provided the

needed proof of the wrap design, giving the state confidence in the system they had specified. Good planning and staging by a quality contractor minimized the impact on the driving public. Training, planning, and cooperation, combined with inspection and testing, delivered a quality project with very few problems. Follow-up testing will provide needed data for strengthening projects in the future.

References

1. Concept Report for I-80 Bridge Rehabilitation, UDOT, October 1998, Section 1, p. 1.
2. Eldredge, S. N., *The Wasatch Fault*, Utah Geological Survey, 1996.

I-80 Bridges

CFRP Manufacturer

Sika Corporation
Lyndhurst, New Jersey

Contractor

Gerber Construction
Lehi, Utah



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