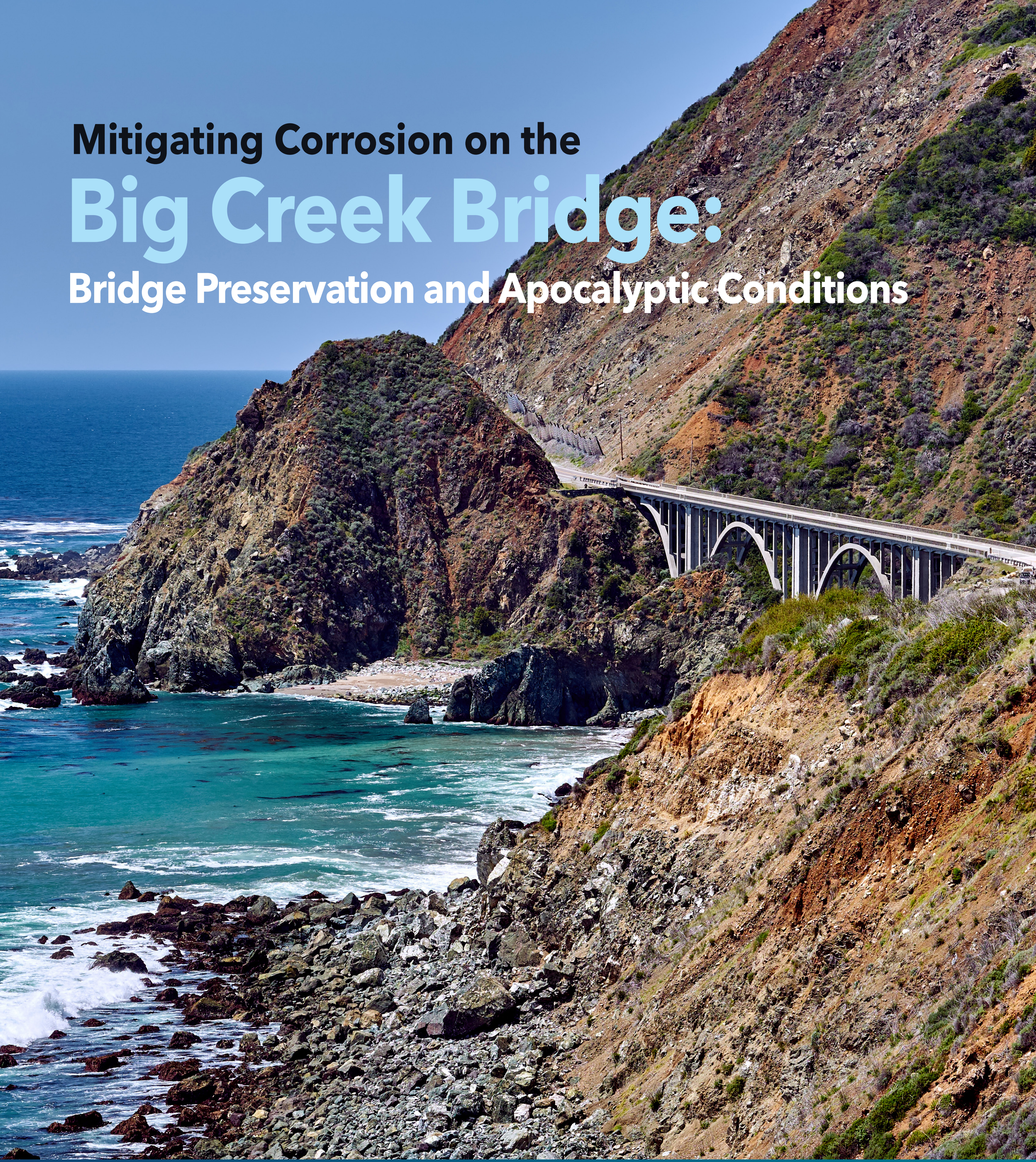
Mitigating Corrosion on the

Big Creek Bridge:

Bridge Preservation and Apocalyptic Conditions



Introduction

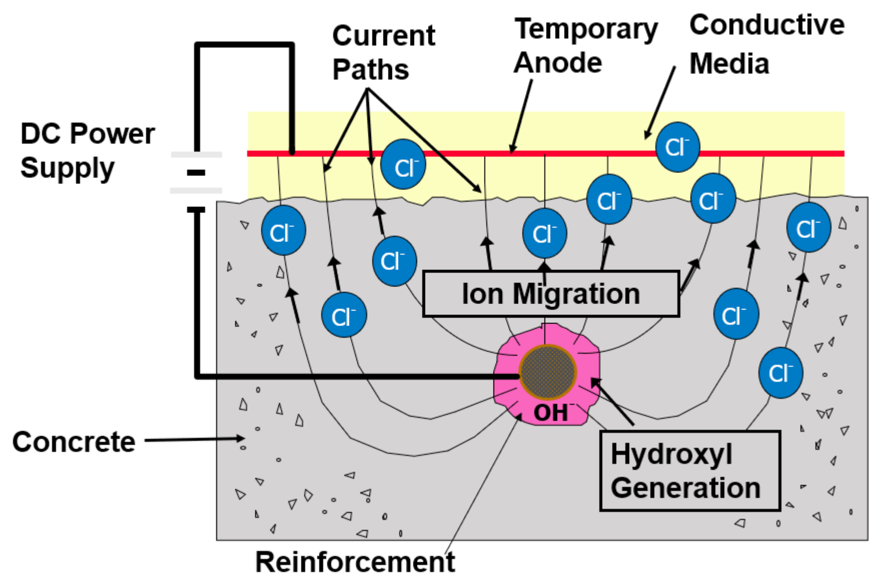
The Big Creek Bridge is a historic structure on California's beautiful Cabrillo Highway. The Highway runs along the Pacific coastline with stunning views of the ocean, and the Big Creek Bridge is worthy of its location. It's not surprising that this gorgeous bridge is one of the most photographed in the country.

The two-lane spandrel arch bridge spans Big Creek Canyon 85 feet above the ground. It's 580 feet long and 24 feet wide. Designed by Christian Theophil Gutleben, the bridge was constructed in 1937.

Its location means the bridge is constantly exposed to airborne salts from the seawater, elements that are especially hard on rebar within the concrete. A 2014 corrosion survey determined that maintenance was needed.

The California Department of Transportation (Caltrans) owns the bridge, and the California Coastal Commission oversees all historical bridges on the Cabrillo Highway. Their top priority was to breathe new life into the bridge while preserving the original look and design. They required a non-destructive treatment that will stop the corrosion. Fortunately, this is our speciality.

Big Creek Bridge Scaffolding Access



Electrochemical Chloride Extraction (ECE) Selection

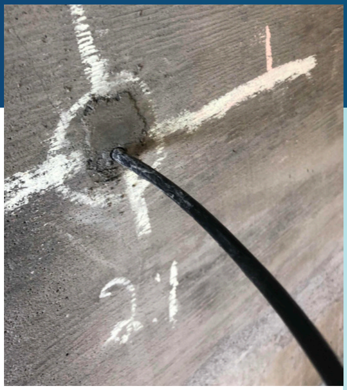
There are many ways to protect bridges from corrosion, but most options fail to preserve the look of the bridge. ECE is a specialized technique that involves temporarily applying a DC current to the reinforcing steel in the concrete. The electrical current draws the chloride ions away from the steel towards the surface of the concrete while boosting the pH of the concrete around the steel. The ECE treatment repassivates the reinforcing steel and returns it to a non-corroding state, like turning back the clock on corrosion. Caltrans and the California Coastal Commission chose this approach for the Big Creek Bridge. Here's how the process works.

Pre-Treatment Testing

A concrete cover and sounding survey was completed over the entire surface. This identified any surface metals that must be removed or isolated to ensure adequate cover over reinforcing steel prior to treatment. The cover depth ranged from 2-3 inches on the spandrel columns and arch ribs. The average stirrup depth was 2.4 inches and the average longitudinal reinforcement depth was 2.6 inches.

Next, an electrical continuity survey confirmed that every rebar being treated was in electrical contact with the overall reinforcing steel grid. The minimum criterion for electrical continuity is a reading of less than 1 mV DC measured between any two points, which was met in all treatment zones.

Finally, dust samples were taken from the spandrel columns, piers, struts, and arches for chloride testing in accordance with AASHTO T260. One chloride sample was taken per 500 sq. feet of concrete area, and at least two samples per structural member. This resulted in 1,536 chloride samples removed using a ¾-inch drill bit at 1-inch increments. Samples were taken within one inch of the nearest rebar and sent to an accredited AASHTO certified laboratory.



Cathode wire connection to the reinforcing steel

Titanium mesh with welded titanium distribution bar

Cellulose matting wrapped in plastic sheet with drip hoses

Installation

Installation of the ECE system started with making cathode connections by locating the reinforcing steel using Ground Penetrating Radar, drilling a ¾ -inch hole to the steel, and making a mechanical connection to the steel. For each monitored sub-zone, a minimum of two electrical contacts were made with a maximum of 500 sq. feet per connection to ensure balanced current distribution.

Next, two layers of ¼-inch cellulose matting were attached to the surface of the concrete using plastic anchors to avoid electrical shorts. The cellulose matting acted as the conductive media that distributed the current uniformly over the surface of the concrete, and also as a spacer between the titanium mesh anode to keep it off the concrete surface.

To keep the cellulose matting wet throughout the treatment, irrigation lines were laid over the horizontal and vertical surfaces to ensure every square foot of the cellulose matting would become saturated with potable water. The water supply hose was connected to a holding tank on top north end of the bridge, and a sump pump was placed within the holding tank to help force water to all areas being treated.

The structure was then covered and wrapped with 6mm clear plastic to retain as much moisture as possible in the cellulose matting.

The anode mesh was wired with two leads running from the junction box to each sub-zone. The redundancy of multiple leads prevents any of the sub-zones from going untreated during the treatment process in case of a connection failure. Each pair of anode lead wires was tested for continuity to ensure good connections to the titanium mesh. A low voltage DC rectifier was set to negatively charge the reinforcing steel and positively charge the titanium anode mesh.

Cellulose fabric attached to concrete surface

Collection tank placed at the bottom of each pier to capture waste water for recirculation

System Monitoring

Before the rectifier was turned on, the cellulose matting was saturated for over a week to provide an ionically conductive media. The rectifier was then switched on and operated in the constant voltage mode.

During the treatment, frequent electrical measurements and system inspections are necessary. Current and voltage output measurements at the rectifier and current measurements for each sub-zone were taken daily to ensure that no connections had failed and that the system was operating correctly.

A visual inspection was also carried out daily to ensure there was no problem with the watering system. The potable water pump, storage tank, and irrigation lines were checked and the cellulose matting was monitored throughout the day for dry spots. As potable water ran through the system, it navigated the concrete members and was ultimately captured in a holding tank at the base of each pier. A jet pump was used to move the water from the base of the pier back to the holding tank at the top of the bridge.

During the ECE treatment, the water will become more acidic. The pH of the storage tank water was monitored and recorded daily and treated as needed to ensure it was at or above a pH of 7. Every week, 1,500 gallons of treatment water were disposed of at a local water treatment facility and replaced with new potable water and the process restarted.

ECE system monitoring

Completion Criteria

The ECE process was specified to run for either 60 cumulative days or until a total of 56 A-hrs per sq. feet of rebar surface area has passed. All three phases were energized for the 60 cumulative days.

After 60 days of treatment, the ECE system was turned off and dismantled for post-treatment testing and clean-up. Chloride testing was performed on each of the three phases. For accurate comparison, post-treatment testing occurred in close proximity to the pre-treatment testing.

Project Challenges

Now this is where it starts to get crazy. The Big Creek Bridge ECE treatment was a success despite many unforeseen challenges the team encountered throughout the project. They arrived to start the pre-treatment testing on April 6, 2020, right after the World Heath Organization declared the novel coronavirus (COVID-19) outbreak a global pandemic.

Fire over the hill near job site

Shortly after mobilizing to site the local plants and wildlife greeted us and we became best friends with the local biologist. A variety of poisonous plants were found in the area that had to be transplanted by biologists. The team was told to watch out for a species of endangered butterfly and rare mushrooms as well. Then, Caltrans found a hummingbird nest and eggs at the top of one of the scaffolding supports and the work was paused while the team waited for the biologist to arrive on site. In June an endangered bat species was found nesting nearby as well and the biologist was called again. Later, the team also had to build soundproof enclosures for the generators so as not to disturb pupping season for the nearby seal colony!

August arrived with a record-setting thunderstorm that ignited fires in the area. A 100-acre fire burned a few miles from the project site. Forest services cut a fire line around perimeter of the bridge. Blocked roads meant working closely with Caltrans and California Highway Patrol to get access to the job site in order to check the state of the bridge.

A separate 19,000-acre fire near Monterey caused thick smoke to blanket the job site. Ditches were on fire, visibility was low, and the roads were closed, making our commute on the winding roads very slow. The team and the Caltrans engineers were escorted by California Highway Patrol. The air quality index was literally off the charts hovering around 515 for weeks, which is considered highly toxic. Great news though, the ECE process wasn't affected, and the team stayed safe by using respirators while continuing to install the ECE system and perform all of the on-site monitoring during that time.

If that wasn't crazy enough, fast forward to January 2021 when a wicked winter windstorm with gusts up to 44 mph lashed the site and actually ripped the enclosures off the bridge.

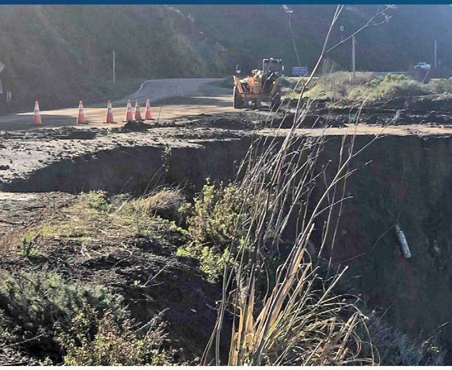
Aftermath of heavy winds and flooding

Flooding and debris

Being in an actual canyon, you can imagine that all this heavy rain triggered flash floods that made its way down the valley and striking the scaffolding with debris. A scaffold company was called in to assess the damage. After the scaffolding was repaired the team got back to work.

Flooding and mudslides didn't just affect us on the project site. A few miles north of the bridge, a large portion of Highway 1 collapsed and was washed into the ocean. Because of this disaster, the highway was closed and the short 4-mile drive from our house to the bridge site turned into a detour of 2-1/2 hours, each way! So ultimately the team decided to relocate to a new housing site on the south side of the bridge, shortening the drive to 1-hour and 20 minutes.

Highway 1 North of Big Creek Bridge wash out



Highway 1 South of Big Creek Bridge erosion

Finally, in February just days after the north side washout and within weeks of project completion the southbound lane started to sluff off into ocean only half of a mile south of the bridge. We were merely feet away from being completely trapped.

Conclusion

Despite all of these wild and unpredictable events, the team successfully completed the ECE treatment of the Big Creek Bridge in February 2021 with zero safety incidents/accidents and the Big Creek site was deemed COVID-free from start to finish thanks to rigorous safety protocols.

The ECE treatment of the arches, spandrel columns, struts, and piers on the Big Creek Bridge was successful and will extend the useful service life of the structure. The treated area was 54,556 sq. feet and the post-treatment chloride concentrations averaged 138 PPM at the level of the rebar, which is below the threshold for corrosion in addition to the increase in alkalinity which occurs as a result of performing ECE.

Based on the data obtained before and after the treatment, it can be concluded that the Electrochemical Chloride Extraction treatment was successful in treating all zones of Big Creek Bridge.

Completed ECE Treatment on Big Creek Bridge