Bridge Preservation over the Oregon Inlet

A History of Concrete Rehabilitation on North Carolina's Outer Banks

By Martin Emmrich

Fig. 1: Herbert C. Bonner Bridge
Photo by Smkybear, courtesy of Flickr.com via Wikimedia Commons

Along North Carolina's Outer Banks, the Oregon Inlet joins the Pamlico Sound with the Atlantic Ocean and separates Bodie Island to the north from Pea Island to the south. It is traversed by a 2.5 mile (4 km) bridge, the Herbert C. Bonner Bridge, which serves as a lifeline for thousands of residents (Fig. 1).

Over 2 million cars cross the bridge annually, providing islanders access to work, schools, and health care on the mainland while also providing access for an important part of North Carolina's annual $19.4 billion tourism industry. With landmarks such as the Cape Hatteras Lighthouse, one-quarter of Dare County's overall economic impact comes from Outer Banks tourism alone.

The Bridge's History

The bridge was built by the North Carolina Department of Transportation (NCDOT) in 1963 for $4.1 million to replace the existing ferry route that could no longer keep up with the growing traffic. It was built without technology and methods considered standard practice today—no epoxy-coated reinforcing steel, no advanced paint coatings for steel members, no enhanced concrete mixture designs, and only a minimal amount of concrete cover over reinforcing steel.

Like many of today's bridges, it has out-lived its intended 30-year lifespan. Over the course of over 50 years, the bridge has taken a beating, including weathering many storms, withstanding corrosive saltwater and air, enduring harsh current, and sustaining numerous boat crashes. The chloride-laden salt air has taken a toll on the bridge's embedded reinforcing steel, creating concrete spalling, and the turbulent waters of the inlet are constantly shifting the sand on the ocean floor, undermining the piers that support the bridge.

"The concrete is essentially rotting from the inside out as salt has found its way to the internal reinforcing steel causing the steel to corrode," said State Bridge Management Engineer Greg Perfetti. "We've also had problems with scour over the years, where the sand around the piers gets washed away" (NCDOT Press Release, 9/4/2013).

Bridge Preservation Efforts

NCDOT wants to replace the structure, but a replacement is on hold due to lawsuits. In the interim, NCDOT started repair work to keep this essential connection to the barrier island open. To date, Coastal Gunite Construction Company has performed three separate concrete rehabilitation projects on the structure.

The first rehabilitation project began in 1987, nearly 25 years after the bridge first opened. Coastal Gunite repaired spalled concrete and damaged reinforcing steel on the bridge bents—everything from the support bearings to the waterline, including bent caps, columns, and footers (Fig. 2).

The project took 2 years, and all distressed concrete was identified, removed, and replaced. The shotcrete mixture used for the repair was a simple 3:1 sand-cement mixture that was batched on-site by the contractor.

"We thought that would be our one and only rehab on the Bonner Bridge. We repaired everything on the substructure and figured they'd build a replacement before anyone had to do more concrete repair," said Curt White, President and Founder of Coastal Gunite Construction Company. "Well, 20 years later, there was no replacement and we were contracted to perform more repairs," he continued.

In 2008 and 2009, Coastal Gunite repaired spalled concrete and damaged reinforcing steel on the bridge bents. In addition, the underside of the superstructure was repaired, including the concrete beams and the underdeck. Interestingly, all the repair work done in this phase was on concrete NOT repaired 20 years earlier. All of the earlier concrete repairs were still in sound condition (Fig. 3).

Then, in 2013 and 2014, Coastal Gunite performed a third round of repairs on the bent caps and underdeck. This repair addressed new areas that were not previously identified for repairs. Both the second and third repair iterations were performed with a prepackaged shotcrete mixture enhanced with silica fume and polypropylene fibers.

Tim Ayers, Coastal Gunite Project Superintendent, oversaw the concrete rehabilitation in both 2008 to 2009 and 2013 to 2014. During these projects, he became intimately familiar with the structure and its past repairs. As a testament to the durability of shotcrete in marine conditions, Ayers maintains that all previous shotcrete repair work has remained intact and all repair work in return visits consisted of newly identified damage to the original concrete.

"We've gone back to spots on the bridge and saw shotcrete patches that were placed 20-plus years ago," said Ayers. "And you know what?

Fig. 2: Chipping of unsound concrete

Fig. 3: Unsound concrete removed

Interesting Fact

Oregon Inlet was formed when a hurricane lashed the Outer Banks in 1846, separating Bodie Island from Pea Island. Similar to other inlets along the Outer Banks, Oregon Inlet moves southward due to drifting sands during tides and storms. It has moved south over 2 miles since 1846, averaging around 66 ft (20 m) per year.

Fig. 4: Freshly shot pier column

Those spots are still solid. They look like they were just shot last week" (Fig. 4).

Repair Challenges

The shotcrete crews faced many challenges performing the bridge repairs over the years. These included finding safe access to hard-to-reach locations as well as dealing with the same site conditions that make it a harsh environment for a bridge. "It's a tough place to work sometimes. There is rain, wind, tides, and fast currents. There's no hiding from the elements on this bridge," remarked Ayers.

Coastal Gunite employed a truck-mounted aerial platform to access a majority of the underdeck work and swing-stage scaffolding to access the columns and footers (Fig. 5). Where feasible, barges were also used to access bent footers.

In some locations, the current was too strong for access by water. "We had to get a snooper truck with a platform attached to get to some spots that we just couldn't reach with our systems," said Ayers. "Also, we had to design our own access system for some spots because of some unique features of the bridge," he added.

Another obstacle was the requirement to vacate the bridge for regular survey inspections. The department installed a series of points marked along 150 of the bridge's 200 spans and uses mobile scanning technology to determine if any of those points have moved. Movement would indicate pile settling, among other things.

Fig. 5: Shotcreting pier cap

On December 3, 2013, Coastal Gunite's crew was working on the bridge substructure when NCDOT determined that the bridge deck had dropped an unsafe level—scour had caused a set of piles to settle. The bridge was immediately closed to traffic and the shotcrete crew was forced to evacuate the project. NCDOT instituted its emergency protocol and implemented ferry service for vehicle access to the island. After an aggressive dredging effort that placed approximately 30,000 yd^3 (22,937 m^3) of sand around piles that were severely scoured, the bridge reopened to traffic on December 15, 2013.

Major Repairs Since 1990[*]

Year	Description
1991	Replaced spans
1992	Scour protection
1994	Riprap
2005	Scour repair
2006	Repair concrete girders
2009	Repair fender system
2008	Add concrete subcaps and pile jackets
2008	Concrete rehabilitation and repair (shotcrete)
2011	Steel repair on channel spans
2011	Scour protection
2012	Install crutch bent and scour protection
2013	Concrete rehabilitation and repair (shotcrete)
2014	Steel crutch bent repairs

[*]Repair projects in excess of $500,000.
Source: North Carolina Department of Transportation

Replacement on the Horizon?

NCDOT first began the process of investing in a new bridge in 1989. Over the course of over two decades, NCDOT has completed many detailed studies analyzing options for replacing the bridge. While several permits have been obtained to proceed with a replacement, lawsuits continue to plague the process.

If all legal and administrative hurdles were cleared today, according to Pablo Hernandez, Resident Engineer for NCDOT, it would take at least 4 years for a replacement to be in place. Therefore, continued evaluation and maintenance of the structure is required.

"You never know," says White, "with required bridge inspections and safety concerns, we may come back yet again to repair more concrete before a replacement is built."

Martin Emmrich *is a Project Manager for Coastal Gunite Construction Company. Based in Bradenton, FL, he has overseen dozens of concrete rehabilitation projects including shotcrete services from New York to Florida. Among others, he is currently managing projects for the Florida Department of Transportation featuring shotcrete repair coupled with cathodic protection.*