STATE

North Carolina

North Carolina continues to invest in infrastructure while exploring innovative construction and repair methods to extend the lifespans of concrete bridges.

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Construction of the new $450 million Alligator River Crossing in eastern North Carolina began in early 2025 and is expected to take four years. More than 700 square precast, prestressed concrete piles are being driven into the Alligator River to support the new bridge. All Photos: North Carolina Department of Transportation.

As the third most hurricane-prone state in the United States, just behind Florida and Texas, North Carolina regularly experiences heavy winds, flooding, storm surge, and tornadoes. North Carolina's coast is especially vulnerable to the effects of hurricanes because it extends into the ocean. However, all areas of the state, from the coast to the mountains, have been affected by hurricanes in the past 20 years.

Hurricane Helene Damage and Recovery

In September 2024, Hurricane Helene produced record rainfall across western North Carolina. Some areas received more than 30 in. of rain, triggering catastrophic flooding and landslides that resulted in more than 100 deaths and an estimated $60 billion in damage to businesses, private property, and transportation infrastructure. Hurricane Helene severely affected critical transportation corridors. The North Carolina Department of Transportation (NCDOT) determined that 674 bridges and 712 culverts were damaged.[1]

Rebuilding in the aftermath of Hurricane Helene presented significant challenges for NCDOT engineers. The widespread destruction and extensive damage to critical infrastructure led to an intense demand for materials, equipment, contractors, and inspectors to support recovery efforts. One of the greatest hurdles during the earliest phases was access, as washed-out roads and bridges made it extremely difficult to reach impacted areas and deliver construction materials and equipment.

As emergency repairs began, the restoration of connectivity gradually made deliveries more feasible, allowing recovery efforts to accelerate. The focus during the initial response was on installing temporary bridges and roadways to restore emergency access for isolated communities and homeowners.

Over time, priorities following the hurricane shifted toward planning and constructing resilient, permanent infrastructure. Balancing the urgency of quickly installing temporary bridges with the long-term need to reconstruct permanent ones was a key challenge. In some cases, temporary structures could be offset from the original alignment to preserve space for future permanent construction; however, in other instances, site constraints required temporary bridges to be built directly on the original footprint, which complicated the transition to permanent solutions.

Close collaboration among NCDOT, the Federal Highway Administration, transportation agencies in neighboring states, industry partners, and local stakeholders proved essential to set western North Carolina firmly on the path to recovery. Lessons learned from this disaster are already influencing how NCDOT approaches emergency response and long-term resilience. By refining strategies for rapid access, resource coordination, and the balance between temporary and permanent solutions, the department will be better prepared to respond swiftly and effectively to future challenges.

Corrosion-Resistant Alternatives

Given the severe coastal environment and the high likelihood of storms affecting the state, NCDOT continues to invest in research and other efforts to increase resiliency, such as ways to prevent and curtail the onset of corrosion in concrete structures. Measures to protect concrete components exposed to chlorides from seawater splash, saltwater spray, or the briny atmosphere include substituting silica fume for a portion of the cement, using corrosion-inhibiting admixtures such as calcium nitrite, and maintaining proper concrete cover.

NCDOT is reviewing the corrosion policy to allow increased use of nonferrous alternative materials to steel reinforcement, including

The new Harker's Island Bridge opened in 2023 and provides improved access to and from the island in emergencies and during hurricane evacuations. The structure is the first in North Carolina to feature carbon-fiber-reinforced polymer strand and glass-fiber-reinforced polymer reinforcement bars.

types of fiber-reinforced polymers (FRPs). Because materials such as glass-fiber-reinforced polymer (GFRP) and carbon-fiber-reinforced polymer (CFRP) are both durable and resistant to corrosion induced by saltwater and harsh environments, their use extends the lifespans of bridges.

The Harker's Island Bridge replacement project was the first bridge entirely reinforced with FRP reinforcing bars and prestressing strand in North Carolina. (For more information on this project, see the Fall 2023 issue of *ASPIRE*®). Given the success of the Harker's Island project, NCDOT has specified FRP reinforcement on other projects, including a bridge replacement over the Alligator River in the Outer Banks region.

Alligator River Bridge Replacement

Currently under construction, the 3.2-mile-long Alligator River Bridge will carry U.S. Route 64 over the Alligator River between the Outer Banks of North Carolina and the mainland. For this project, NCDOT selected a construction manager/general contractor project delivery method to accelerate the schedule.

The new structure, which replaces a swing-span bridge that is more than 60 years old, has a high-rise, fixed span over the navigation channel with a horizontal clearance of 140 ft and a vertical clearance of 65 ft. The new cross section consists of two 12-ft-wide travel lanes with 8-ft shoulders for a total width of 40 ft.

The bridge consists of 134 spans with lengths ranging from 80 to 170 ft over the channel. Precast, prestressed concrete girders and a cast-in-place concrete deck comprise the superstructure, and concrete link slabs are specified to eliminate joints. Corrosion-resistant design features include CFRP prestressing strands in the precast concrete piles and GFRP reinforcement in the cast-in-place concrete substructure. The square precast concrete piles are 24, 36, and 54 in. with lengths that range from 89 to 125 ft. The design also incorporates GFRP reinforcement in the concrete deck.

Marc Basnight Bridge

The 14,800-ft-long Marc Basnight Bridge, which serves the Outer Banks, is another example of corrosion-resistant design. (See the Fall 2019 issue of *ASPIRE* for a Project article about the Marc Basnight Bridge.) For the first time in North Carolina, stainless steel was used in place of traditional carbon steel reinforcement, specifically in the cast-in-place concrete bridge deck and the post-tensioning bars. In conjunction with the stainless steel reinforcement, advanced concrete mixtures and precast concrete components were used to help achieve the design goal of a 100-year service life. The concrete mixture proportions used for the Marc Basnight Bridge were selected for maximum durability against saltwater exposure. Calcium nitrite corrosion inhibitor coupled with supplementary cementitious materials, including fly ash, slag, and silica fume, decrease the permeability of the concrete and help delay the onset of corrosion in the steel reinforcement.

Sampson County Bridge No.3 is the first North Carolina example of a retrofit application using the prestressed, mechanically fastened, fiber-reinforced polymer system. The repair of six beams was completed in five days, and the bridge reopened immediately after installation of the repair.

Beyond Coastal Corrosion

The "belt and suspenders" approach of corrosion protection for bridges along the coast makes sense, but there are other areas of the state that can benefit from additional measures to protect bridges from corrosion. For example, structures in locations that require deicing agents in the winter are also at risk for corrosion-related damage. For this reason, NCDOT is evaluating the use of FRP bars in concrete bridge decks statewide.

NCDOT has constructed four bridges using FRP materials for reinforcement, with two more under construction. Currently, NCDOT is giving contractors on awarded projects the option to substitute FRP bars for steel reinforcement in concrete decks, when feasible, while the development of design guidance is completed. The new guidelines will include deck design tables for use by designers and a flowchart that demonstrates when FRP should be a priority to achieve a minimum service life of 75 years. This approach promotes the use of FRP instead of carbon steel for both strand and reinforcing bar in known corrosive environments and ensures that bridge decks are protected. For bridges in corrosive areas, the flowchart indicates that all prestressed concrete girders shall be designed for zero tension in the precompressed tensile zone to minimize cracks.

The Marc Basnight Bridge is designed to resist corrosion in the harsh saltwater environment of coastal North Carolina. To meet the 100-year service life, the design team chose stainless steel reinforcement for the cast-in-place concrete deck.

Mapping Corrosive Environments

The NCDOT Structure Management Unit Manual[2] includes a Corrosive Areas Map that delineates both "corrosive" and "highly corrosive" lines along the coast and inland to the Albemarle Sound. NCDOT is trying to clearly locate corrosive environments in the state and identify when to use corrosion-resistant materials such as GFRP.

A 2022 research project[3] by the University of North Carolina at Charlotte examined whether the specified cover requirements, use of fly ash and silica fume, and corrosion-inhibitor dosage rates described in the NCDOT's Structures Management Unit Manual were consistently delaying the onset of corrosion in coastal concrete bridges. The study proposed further evaluation of the current method of delineating high-corrosion zones.

Beyond coastal areas, NCDOT can use in situ testing to pinpoint potentially corrosive environments. The follow-up research aims to develop improved corrosion mitigation strategies for long-term durability, possibly by analyzing water samples to assess chloride exposure and site aggressiveness.

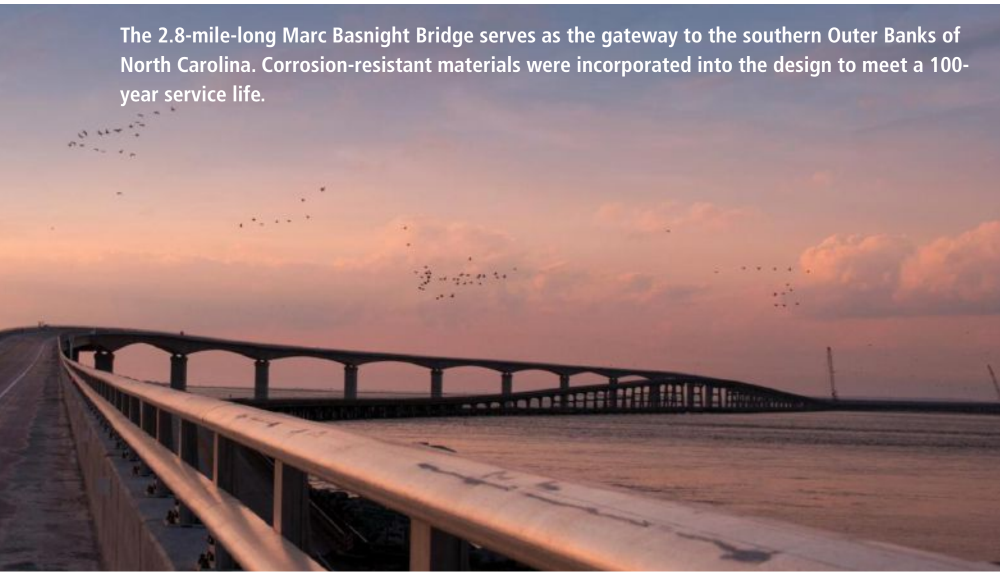
Rapid Repair of Prestressed Concrete Bridge Beams

In conjunction with North Carolina State University (NCSU), NCDOT has examined innovative approaches to restore the integrity of concrete bridges with corroded prestressing strands. The prestressed, mechanically fastened, fiber-reinforced polymer (MF-FRP) system has been used primarily on prestressed concrete channel and cored-slab beams to provide a type of temporary repair that can be rapidly completed to extend the structure's use until it can be replaced.

In November 2020, six channel beams on Sampson County Bridge No. 3 were retrofitted with the prestressed MF-FRP system as a temporary solution for a deteriorated structure. The bridge is a three-span prestressed concrete channel structure built in 1966 across Branch Six Run Creek, and the retrofit was designed to restore prestressing forces lost due to corrosion of internal steel strands. The cost-effective repair allowed the bridge to be reopened immediately; the bridge's condition was then continuously monitored until the structure was replaced. The new bridge opened to traffic in 2023.

Similar repairs were performed on Franklin County Bridge No. 80 and Wake County Bridge No. 180. These projects demonstrate that with a small NCDOT crew, many structures can be repaired and kept in service, typically with an increased load posting, until a permanent solution can be implemented.

NCSU continues to study the MF-FRP system by evaluating the repaired girders as they become available when retrofitted bridges are replaced. Specifically, the investigators can determine the residual strength in the repaired girders after being in service for typically two to three years. With that information, NCDOT should be better able to determine the extended service life of the repaired components. The research team is salvaging the six retrofitted channel beams from Sampson County Bridge No. 3 that were in service for approximately 21 months. Two additional beams from the bridge will serve as controls for comparison at the laboratory. The MF-FRP rapid-repair system is discussed in detail in the Fall 2024 issue of *ASPIRE*.



The 2.8-mile-long Marc Basnight Bridge serves as the gateway to the southern Outer Banks of North Carolina. Corrosion-resistant materials were incorporated into the design to meet a 100-year service life.

Conclusion

NCDOT faces a variety of challenges when designing and constructing resilient concrete bridges. North Carolina's existing infrastructure, including its bridges, is susceptible to damage from exposure to corrosive environments as well as flooding and high-water events. The agency uses innovative techniques to repair existing concrete structures and design new bridges to withstand environmental impacts.

References

1. North Carolina Office of State Budget and Management (OSBM). 2024. *Hurricane Helene Recovery—Revised Damage and Needs Assessment*. Raleigh, NC: OSBM. https://www.osbm.nc.gov/hurricane-helene-dna/open.
2. North Carolina Department of Transportation (NCDOT). 2023. *Structures Management Unit Manual*. Raleigh, NC: NCDOT. https://connect.ncdot.gov/resources/Structures/StructureResources/SMU%20Design%20Manual.pdf.
3. Tempest, B., T. Cavalline, R. Newsome, K. Violette, and T. Al-Salihi. 2022. *Evaluating Corrosive Sites Policy for Concrete Bridges at the North Carolina Coas*t. Raleigh, NC: NCDOT. https://connect.ncdot.gov/projects/research/RNAProjDocs/RP2019-22%20Final%20Report.pdf.

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