PROJECT

Rapidly Restoring a Vital Transportation Route in Nebraska

by Ross Barron, Olsson

A rare bomb cyclone that hit Nebraska on March 12, 2019, caused the failure of the Spencer Dam in north-central Nebraska. The resulting flood damaged the existing U.S. Highway 281 bridge over the Niobrara River and created a new channel of the river that destroyed 1000 ft of pavement south of the bridge. Until a temporary bridge was installed, users had to endure a two-hour detour.

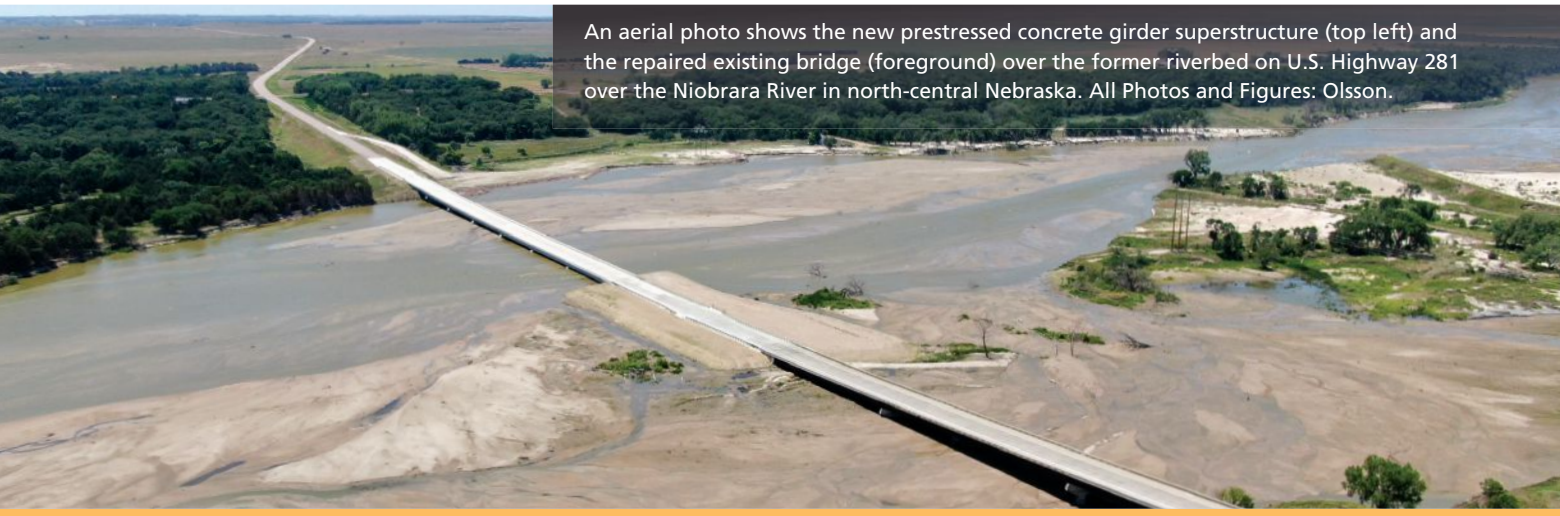
Weather experts called it a perfect storm but, in reality, there was nothing perfect about the weather events that hit Nebraska with a wallop never before seen in the Cornhusker State.

On March 12, 2019, the state was hit by a rare bomb cyclone, which is a storm caused by a steep drop in barometric pressure. The results were blizzard conditions in the west, heavy rains in the east, and Category 3 (111 to 129 mph) hurricane-force winds throughout the state.

What made this storm unique was not so much the amount of moisture as the timing. Nebraska was coming out of a severe winter with heavy snow and colder-than-normal temperatures that had frozen the soil to a depth greater than 1 ft in the weeks leading up to the storm, and creeks and rivers were iced over. When the rain hit the eastern part of the state, nothing could slow a massive runoff of up to 3 in. of rain and rapidly melting snow.

Widespread Damage and Destruction

As a result of this bomb cyclone, several major drainages in central and eastern Nebraska flooded simultaneously, causing levees to fail throughout the state. Nearly 200 miles of highway, 30 state bridges, and a plethora of county roads were either damaged or destroyed. One of the damaged roadways spanned the Niobrara River on U.S. Highway 281 (U.S. 281) in north-central Nebraska. Massive ice floes in the Niobrara River to the west of an existing bridge resulted in failure of the Spencer Dam, which



An aerial photo shows the new prestressed concrete girder superstructure (top left) and the repaired existing bridge (foreground) over the former riverbed on U.S. Highway 281 over the Niobrara River in north-central Nebraska. All Photos and Figures: Olsson.

profile

HIGHWAY 281 OVER THE NIOBRARA RIVER EMERGENCY RESPONSE / BOYD AND HOLT COUNTIES, NEBRASKA

BRIDGE DESIGN ENGINEER: Olsson, Lincoln, Neb.

PRIME CONTRACTOR: Hawkins Construction Company, Omaha, Neb.

PRECASTER: Concrete Industries, Lincoln, Neb.—a PCI-certified producer

OTHER MATERIAL SUPPLIER: Temporary prefabricated modular bridge supplier: ACROW Bridge, Parsippany, N.J.

A view of the skewed ends of the NU1800 prestressed concrete girders at an abutment. This photo was taken before the semi-integral abutment turndown placement and before the deck forming and concrete placement. This bridge featured a jointless deck system across the length of the structure. Expansion joints were placed at the end of the approach slabs, which were founded on pile-supported grade beams placed 20 ft beyond the abutments.

subsequently and dramatically created a brand-new path for the Niobrara River. The flooding left a wide path of destruction, including damage to the existing bridge and 1000 ft of pavement at the south end of the bridge.

The damaged pavement and bridge affected residents of Boyd and Holt counties in big ways. Because the bridge was out, two-hour driving detours to work, school, medical care, and other important resources were the norm. Something had to be done to help those affected—and fast.

An engineering and design firm was tapped to evaluate the damage, develop a solution that would restore highway traffic quickly, and design a new connection across the new river alignment. The design team understood the challenge at hand and that time was of the essence.

Early in the project, it became clear that the Nebraska Department of Transportation would have to bid the repair of the existing bridge, construction of a temporary roadway and bridge, and construction of the permanent roadway and bridge all together. A design project this massive would typically take a year or more to get ready to bid.

How difficult was this task? First came the realization that to restore traffic for this essential highway route in just four months meant setting an internal deadline of April 17, 2019, to complete design work for bidding. That gave the engineering design team four weeks to design two bridges—one temporary, one permanent. It took the efforts of technical experts across the firm to quickly mobilize, coordinate, and get to work. Everyone on the team knew that these were not ordinary circumstances and took to heart the mission at hand.

When teammates traveled to the site to better understand the engineering challenge, they witnessed the utter devastation of the landscape. The river was still raging because of very high flows, and the edges of the river were unstable and continuing to erode

Girders are set and are being prepared for concrete deck placement on the U.S. Highway 281 Bridge over the Niobrara River. This photo is taken from the south bridge abutment looking along the bridge span over the new river channel. A temporary crossing for contractor access was constructed adjacent to the permanent bridge to allow cranes to access the jobsite and place girders. Multiple cranes were on site during construction, and space was generally limited between the temporary bridge and the permanent bridge.

NEBRASKA DEPARTMENT OF TRANSPORTATION, OWNER

BRIDGE DESCRIPTION: A 1050-ft-long, seven-span, continuous, prestressed concrete I-girder bridge

STRUCTURAL COMPONENTS: Thirty-five NU1800 precast prestressed concrete I-girders with an 8-in.-thick, cast-in-place concrete deck; cast-in-place concrete substructure units on driven-pile foundations

CONSTRUCTION COST: $26.5 million

AWARDS: American Council of Engineering Consultants (ACEC) Nebraska 2020 Grand Award Winner, ACEC 2021 National Recognition Award

Looking along the NU1800 precast, prestressed concrete girders toward one of the permanent bridge piers.

quickly. The design team quickly made an accurate aerial topographic survey so that the engineers could get to work.

With aerial photography and site geotechnical sampling, experts in fluvial geomorphology and hydrology provided invaluable insights into the Niobrara River's new path and how it would continue to evolve over time. These experts furnished recommendations for temporary and final construction that accounted for the long-term behavior of the new river alignment. Recommendations included designing the new bridge to span nearly the entire width of the new channel, which would be more cost effective and would allow the new channel to naturally adjust as necessary within the reach.

The channel elevations were expected to be high during construction but to decrease over time, so pier and pile caps were designed for the lower long-term elevations and 10 ft or more of excavation was required. Several bank stabilization and flow deflection alternatives were evaluated for erosion control, but because of environmental concerns and regulatory restrictions, an off-channel countermeasure was needed. Therefore, workers constructed a buried sheet-pile wall set back from the river bank to prevent erosion from extending beyond that point. In addition, long-term monitoring was recommended to identify and assess any issues related to the combination of predicted sedimentation within and upstream of the bridge reach and winter ice formation and jams.

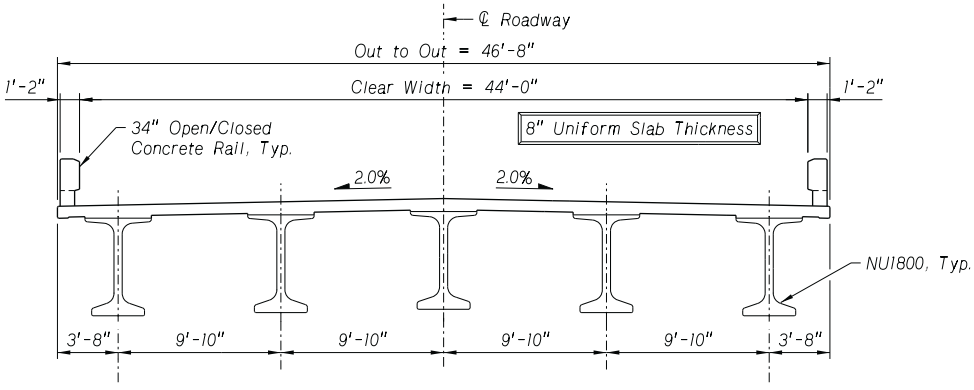
Temporary Bridge

The bridge engineers worked to develop a temporary bridge across the new river alignment that could be deployed as quickly as possible. The Nebraska Department of Transportation helped find available modular prefabricated bridge manufacturers to help on multiple projects throughout the state. The design team coordinated with suppliers early in the design phase and developed a partnership with a company that was dedicated to quickly providing materials to support the state in its efforts to restore the highway system across Nebraska. The results of the hydraulic and structural alternative analysis led to the design of a six-span, 600-ft-long modular bridge within the limits of a relatively stable portion of the new river channel. This temporary bridge was intended to be the in-service detour route for more than a year, so the engineers needed to consider how the river conditions might shift or evolve seasonally during that time. Temporary roadway connections on each end of the bridge were made using a significant amount of rock riprap to stabilize the sand base of the riverbed. The temporary bridge was designed, bid, and constructed rapidly, and highway traffic was restored just four months after the flooding disaster.

Concurrently with the development of a temporary bridge and roadway solution, the design team was also hard at work providing the design for repair of the existing bridge and the permanent solution for the new river crossing. Following the dam failure, the existing bridge was damaged by an 11-ft wall of ice chunks the size of trucks. Luckily, simple repairs allowed the contractor to quickly restore the structural viability of that bridge.

Permanent Bridge

The permanent bridge design crossing the new river channel was not a simple task. The hydraulic analysis considered the current and future conditions of the new river channel, including the potential for the braided channel to shift significantly over time, and showed that a 1050-ft-long bridge would be necessary to span the new river channel. For economy, simplicity, and durability reasons, a prestressed concrete girder superstructure was selected as optimal for the site. A seven-span bridge using NU1800 girders made continuous for live



Typical cross section of the new bridge. The girder design required fifty 0.6-in.-diameter strands and a design concrete compressive strength of 10 ksi.

Aerial view of the new bridge location from the south abutment, with the existing bridge in the background. The hydraulic analysis and bridge design considered the current and future conditions of the new river channel, including the potential for the braided channel to shift and the channel bottom to lower significantly over time. The new bridge was constructed on the original alignment to the right of the temporary work bridge, which was also used to construct the temporary modular bridge used to restore traffic.

load with a 20-degree skew with respect to the girders and consisting of 155-ft central spans and 140-ft end spans was determined to be structurally and hydraulically optimal. The bridge was jointless across the length, with expansion joints provided at a pile-supported grade beam at each end of the approach.

The girder design required fifty 0.6-in.-diameter strands and a design concrete compressive strength of 10 ksi.

The project encountered fabrication challenges that were mostly centered around availability. Girders were being cast for bridges across the state, and the girder fabrication timeline drove the construction schedule. Erection required a temporary crossing between the permanent and temporary bridges to enable the contractor to deliver and place the girders.

One of the key challenges for designing the permanent bridge was developing an understanding of how the new channel of the Niobrara River would evolve over time and the role the flow-line elevation and scour would play in the stability of the bridge foundation. The failure of the dam upstream would lead to aggradation for a time. Judging from the upstream and downstream conditions, it was clear the channel would eventually normalize to a bottom-of-channel elevation well below the postflood condition. Because of contractor availability and the expediency of the project, it was determined that driven-pile foundations constructed with cofferdams would be more economical than drilled-shaft construction and would aid in the constructability of the project. Although challenging to deploy in the evolving river conditions, this approach provided for a structure that could endure channel conditions that were expected to vary dramatically between the bridge's short-term and the long-term service lives.

The approach used to address the project requirements worked well. The engineer met the April 17 deadline for the design of the project, and the estimated project cost for the temporary and permanent bridges, the associated roadway, and the repairs to the existing highway bridge closely matched the awarded bid. Considering the devastation across the state, designing, bidding, and constructing the project quickly was of paramount importance. The contractor that was awarded the project became a close partner with the design team to maximize efficiency on the project, and crews worked long hours to permanently restore the highway.

How daunting was this project? The engineer's technical leader said he had never seen anything like it in his more than 25 years in the profession.

A Feat of Engineering

The temporary bridge opened on July 26, 2019, a week ahead of schedule, providing a vital route for local residents. Restoring the major transportation route was essential to the economy of north-central Nebraska. The bridge closure had forced some motorists to take detours as long as 127 miles, adding two hours to necessary trips that formerly took only minutes, according to Derek Bentz, chair of the village board in nearby Spencer.

Restoring the traffic across the river in fewer than four months required extraordinary coordination and a lot of hard work. This project truly demonstrated the importance of engineers within our community. At the celebration of the opening of the new bridge in October 2020, Nebraska governor Pete Ricketts said of the $26.5 million project "It was an incredible feat of engineering and construction that everybody came together to make this happen. It really has been a testament to the partnerships in our state."

Ross Barron is a lead engineer for the Nebraska Roads and Bridges team at Olsson in Lincoln, Neb.