PROJECT

U.S. Route 54 over the Canadian River

New Mexico's First Cast-in-Place Concrete Segmental Box-Girder Bridge

by Nyssa Beach, Jacobs Engineering, and
Jeff Mehle, McNary Bergeron & Associates

The new alignment of U.S. Route 54, with the nearly completed concrete segmental box-girder bridge, is offset just east of the existing alignment with its aging deck truss bridge. Photo: Malcolm International.

Amid the expanse of rural desert in northeastern New Mexico is the small, agriculture-centered village of Logan. In Logan, the Canadian River, which cuts deeply through the desert landscape, is crossed by a steel deck truss bridge carrying U.S. Route 54 (U.S. 54). This bridge is steeped in the rich history that brought commerce trails, rails, and roads to the area. Currently, the U.S. 54 corridor is the main trucking route from Chicago, Ill., to El Paso, Tex., with over 50% truck traffic. Additionally, it provides access to Ute Lake State Park—Ute Lake is the second largest lake in New Mexico and is popular with water and fishing enthusiasts.

The new U.S. 54 Canadian River Bridge is an exciting first for the state of New Mexico and a new chapter for the area's transportation future: a cast-in-place segmental box-girder bridge. This bridge, built with the balanced-cantilever method, was designed to replace a 1954 steel truss structure while also minimizing impacts to the Canadian River, the river's protected inhabitants, and the surrounding wetlands, as well as to adjacent historic and prehistoric archaeological sites. The new structure addresses the deficiencies and poor condition of the load-restricted steel deck truss bridge, thus improving safety and ensuring the future viability of the U.S. 54 corridor.

The New Mexico Department of Transportation (NMDOT) and the design team met the challenges of this unique location by conducting a comprehensive alignment and structure selection study while engaging public input. The result is a three-span segmental structure with a sweeping alignment that is offset just east of the existing river crossing.

Designing a Bridge for a Unique Location

The design of the Canadian River Bridge balances both the structural and functional requirements of the project. The new 43-ft-wide cross section includes two 12-ft-wide lanes, 8-ft-wide shoulders on each side, and barriers. The pier locations were carefully considered during design to minimize environmental impacts and avoid the river's floodplain. The three-span configuration was optimally set at 200, 325, and 210 ft. The box-girder depth varies from 18 ft at the piers to 8 ft at midspan and at the abutments. This segmental box-girder structure is on a 3000-ft-radius horizontal curve with a constant 4% cross slope.

During the balanced-cantilever construction, the superstructure was consistently built a half segment out of balance on either side. Each pier table was built out to be half a segment longer on one side such that when the 15-ft-long segments were cast on either side of the cantilever, the superstructure was only ever half a segment out of balance at any time. The design of the twin-wall columns efficiently handled the large out-of-balance moment during construction and carried it as a couple to the foundation. The piers and abutments are founded on deep concrete drilled shafts.

Project Challenges

Constructing a bridge in rural northeastern New Mexico presented several unique challenges to the U.S. 54 Canadian River Bridge project team.

profile

U.S. ROUTE 54 CANADIAN RIVER BRIDGE / LOGAN, NEW MEXICO

BRIDGE DESIGN ENGINEER AND OWNER'S ENGINEER: Jacobs Engineering, Denver Colo.

PRIME CONTRACTOR: Fisher Sand & Gravel New Mexico Inc., Placitas, N.Mex.

SEGMENTAL CONTRACTOR: Malcolm International, Rancho Cordova, Calif.

CONSTRUCTION ENGINEERING: McNary Bergeron & Associates, Broomfield, Colo.

POST-TENSIONING SYSTEM AND FORM TRAVELER SUPPLIER: Schwager Davis Inc., San Jose, Calif.

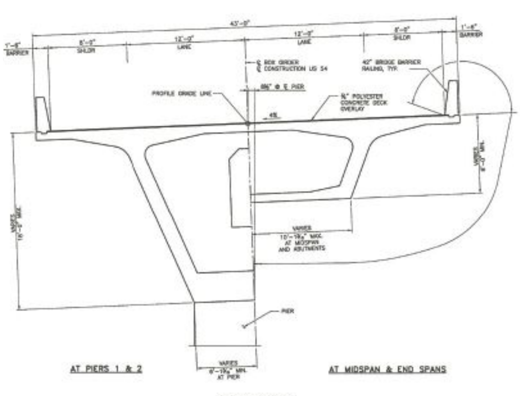
With the bridge about half complete, multiple construction operations were underway concurrently, including the nearly completed balanced-cantilever construction of cantilever 1, construction of pier table 2, and construction of both end spans on falsework. Photo: Malcolm International.

The new U.S. 54 alignment is on a sweeping 3000-ft-radius horizontal curve. Photo: New Mexico Department of Transportation.

Remote Location

Logan is approximately 200 miles east of both Albuquerque, N.Mex., and Santa Fe, N.Mex., and 100 miles west of Amarillo, Tex. It has a population of just over 1000 and is home to ranching and agriculture, as well as recreation at Ute Lake State Park.

The availability of workers with bridge construction experience was limited in Logan. Most of the workers were from out of town or out of state. Scheduling of major construction tasks needed to take workers' holidays and trips home into account. The remote site also led to a high turnover of laborers, which extended the learning curve associated with constructing a segmental bridge. To minimize the impact of the high turnover rate, a core group of key field staff members was relocated to New Mexico and remained consistent throughout the project. This helped keep consistency in key roles despite turnover challenges with construction staff in the remote project location. The segmental contractor also used three-dimensional sketchup models for workforce training to efficiently bring on new workers, as needed, and get them up to speed on the segmental construction and, in particular, the procedures, quality control, and terminology associated with each part of segmental construction. Scheduling, training, and coordination between tasks and operations was imperative for meeting the construction schedule.



Typical bridge section showing the box-girder depths, which vary from 18 ft at the piers to 8 ft at midspan and at the abutments. Figure: New Mexico Department of Transportation.

Brine Aquifer

During the final design phase, a specific challenge for the design team was the presence of a brine aquifer deep below the project site. If the aquifer were disturbed during construction, the high chloride concentration from the aquifer would contaminate the water supply downstream. Due to the aquifer's varying depth amid thin mudstone or siltstone layers, the greatest risk for penetration was around pier 2. The design team worked closely with the Canadian River Municipal Water Authority to weigh the risks and determine the best path forward. The final design mitigated risk by increasing the size of the pier footing and drilled shafts, which in turn allowed the shafts' lengths to be shortened.

The project's special provisions required the contractor to have a containment plan and system in place in the unlikely event that the drilling operations penetrated the aquifer. This containment plan included testing water samples from the Canadian River before drilling for a baseline and again after installing the drilled shafts. Provisions for capture and disposal of brine water were identified in case the testing showed elevated levels of saline. Although this phase of construction had uncertainty and potential risk, the drilling and shaft installation did not ultimately impact the brine aquifer and no additional mitigation measures during construction were required.

NEW MEXICO DEPARTMENT OF TRANSPORTATION, OWNER

OTHER MATERIAL SUPPLIERS: Reinforcement: CMC Rebar, Albuquerque, N.Mex.; bearings: D.S. Brown Company, North Baltimore, Ohio; expansion joints: Watson Bowman Acme, Buffalo, N.Y.; prepackaged grout: US SPEC, Denver, Colo.

BRIDGE DESCRIPTION: Three-span, 735-ft-long, post-tensioned, cast-in-place concrete segmental box-girder bridge

STRUCTURAL COMPONENTS: 38 variable-depth cast-in-place concrete segmental box-girder segments and three closure segments, end spans cast on falsework, monolithic twin-wall columns, pier footings, and drilled-shaft foundations

BRIDGE CONSTRUCTION COST: $22 million

Form travelers at either end of cantilever 1. Geometry control and monitoring during segment casting ensured accurate vertical and horizontal alignments. Photo: Malcolm International.

Concrete

For segmental construction, a high-performance concrete is required. This bridge's design specifically required concrete with a 28-day compressive strength of 6000 psi, and a 3500-psi minimum strength was required prior to tensioning the post-tensioned tendons. To meet the fast-paced construction schedule of the desired seven-day casting cycle, a high-early-strength concrete mixture was ideal.

To achieve a concrete mixture that met these requirements, more than 20 trial batches using local materials and admixtures were tested. A concrete mixture with an 8 to 9 in. slump to facilitate placement among congested reinforcement and a strength of 3500 psi within 12 hours was achieved.

The project's concrete supplier was located in Tucumcari, N.Mex., 25 miles south of the project site. To address the challenges of producing a special concrete mixture and transporting it over 30 minutes by truck, the contractor opted to set up a temporary batch plant at the project site. The on-site facility enabled easier communication and immediate response times, and provided concrete production that met the project specifications and demands.

Weather

Logan is located at an elevation of approximately 3800 ft above sea level, with a relatively dry climate. However, this region also sees a wide range of temperatures—with high temperatures above 100°F during the summer, and lows below freezing with periodic snow in the winter—and experiences extreme weather swings throughout the year. These drastic weather swings can occur within the same week or even within a 24-hour period.

Another weather obstacle for construction operations and schedule are high, gusty winds, which are common in this area. In March 2019, wind gusts of over 60 miles per hour derailed two dozen train cars on a rail bridge downstream from the project.

Design Support During Construction

Throughout the segmental construction, the project team—NMDOT, the design team, and the contractor—worked together to collaborate on the successful execution of vital construction operations.

Comprehensive Concrete Repair Plan

The design engineer and NMDOT coordinated with the segmental contractor to develop a comprehensive concrete repair plan that could be used as necessary throughout the construction to address repairs efficiently and effectively. In the early development of the optimal concrete mixture, concerns arose about slump, the effect of the dry desert climate on the mixture, and consolidation issues. Nondestructive testing, including the impact-echo method, was conducted in areas of significant repair to provide assurance and confidence regarding the quality of the final product.

Post-Tensioning and Grouting

During segmental post-tensioning operations, the design team and the contractor's engineer worked to fine-tune the design parameters based on field-verified values. The theoretical design prestressing parameters for

AESTHETICS **COMMENTARY**

by Frederick Gottemoeller

The challenge of inserting a new bridge into a spectacular natural scene is to design the bridge so that it complements, not clutters, the landscape. A new bridge will unavoidably become the center of attention, but it shouldn't fight for that attention. It should look like it has always been there. One way of accomplishing this is to fit the features of the bridge into the physical features of the site in an obvious and natural way. Here, the piers of the U.S. Route 54 bridge rest on the valley's slopes, out of the floodplain. Plus, the blocky, unadorned pier shafts give the piers an appearance similar to the blocky boulders of the nearby bluffs.

Simplicity itself usually helps fit a new bridge into a spectacular scene. That characteristic should extend to the basic geometry. Here the geometry consists of three horizontal curves: two at each end of the project to create the departure from U.S. 54, and a single, long curve in the middle. Its overall length matches the bridge to the scale of the desert landscape. Imagine how different the bridge would have looked if the designers had decided, for reasons of construction simplicity, to make the bridge straight. There would have been two short curves at each end of the bridge with a straight section in the middle, creating the "broken back curve" dreaded by highway engineers. The bridge would have had a choppy, cut-up appearance, completely out of place in this sweeping landscape.

Sloping the webs of the box girder is another direct, natural way of increasing the sculptural interest of the bridge. Simply by their geometric interplay with the haunches of the girders, the sloped sides create curved edges and varying widths for the girder soffits. Finally, deepening the haunches over the piers visually demonstrates the natural distribution of forces in the bridge, something I imagine the school kids in Logan grasped intuitively when they were given a chance to learn about the structure.

Closure beams were used to align and grade the cantilever tips and end spans for casting the closure sections. Photo: Malcolm International.

Formwork being set in preparation for casting the next box-girder segment. Photo: Malcolm International.

friction and wobble were compared with the actual observed coefficients measured in the field, with field friction tests and elongation compared with force results for each length of tendon. Additionally, post-tensioned tendon tensioning results were tracked to identify elongation trends during the progression of the cantilever segments. The cantilever tendon elongations during construction were compared to an allowable ±7% tolerance on the elongation difference between actual and theoretical values. This was valuable in recognizing trends to anticipate and understand the results and quickly address any anomalies.

The 38 top slab cantilever-construction tendons at each pier were composed of fifteen 0.6-in.-diameter strands. After the closure segments were cast, bottom slab continuity tendons—10 tendons with fifteen 0.6-in.-diameter strands in the end spans and 14 tendons with eighteen 0.6-in.-diameter strands in the center span—were tensioned. All continuity tendon ducts were sized for 19 strands as a provisional allowance. Six high-strength $1\frac{3}{8}$-in.-diameter post-tensioning bars were also used in each end span.

In December 2019, the U.S. Route 54 project team gave presentations on the cast-in-place segmental concrete box-girder bridge to students of the Logan Municipal Schools. The students also participated in hands-on activities related to bridge construction. Photo: Logan Municipal Schools.

Before post-tensioned tendon grouting operations began, the U.S. 54 project team worked together with the American Segmental Bridge Institute (ASBI) to host ASBI Grouting Certification Training on site. This training provided valuable support and guidance ahead of the grouting operations, which were crucial to the long-term protection and durability of the structure.

Geometry Control

An essential aspect of cast-in-place segmental construction is geometry control. As box-girder segments are cast at either end of the cantilever, the geometry of the bridge is monitored with the ever-changing conditions, and adjustments are made with each casting. The geometry is constantly checked for agreement with the theoretical geometry, while also taking into account and correcting for the as-built conditions.

On the U.S. 54 project, geometry control was led by the contractor's construction engineer and survey team. Geometry-control quality assurance was performed independently by the design team and verified in survey checks. At the closure segments, the tips of the segments were aligned to within $\frac{1}{2}$ in. of each other in both the vertical and horizontal geometry. This accuracy demonstrated the success of the geometry-control coordination and minimized cast-in correction forces.

"This Is *Your* Bridge"

During segmental construction, representatives from NMDOT, the design engineer, and the segmental contractor came together to give two interactive presentations for students in the Logan Municipal School District. At the time of the presentations, the residents of Logan had been observing the progress of the segmental structure for over a year. The students and school staff were therefore brimming with questions and eager to learn about the project. These educational presentations provided an opportunity to share project information and technical design facts, demonstrate career paths in engineering and skilled trades, and help the students develop a sense of ownership of their community's exciting new bridge. After the presentations, the students participated in hands-on activities to learn more about different bridge construction elements, including a tendon anchorage assembly, a reinforcement cage, concrete cylinders, personal protective equipment, and design drawings.

Conclusion

The U.S. 54 Canadian River Bridge project team worked in harmony with the rural and sensitive environment at the site to develop a bridge that is well suited to its beautiful and unique location. Segmental construction was completed in July 2020. Following the completion of a polymer concrete overlay placement, approach roadway, and tie-in to the new river crossing, traffic will be moved to the new structure and the existing steel deck truss bridge will be removed.

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