SUCCESS WITH STEEL: THE I-25/PASEO DEL NORTE INTERCHANGE RECONSTRUCTION FLYOVER

AMANDA WHITE, PE

BIOGRAPHY

Amanda White is an alumnus of New Mexico State University, having acquired a BS in Civil Engineering and a MS in Structural Engineering. She is a Structural Engineer and Project Manager with Bohannan Huston. Mandy is a registered PE in New Mexico and has experience designing and managing bridge projects in New Mexico and Colorado. She specializes in the structural support of interchange projects as well as corridor bridge projects. She has experience with pedestrian bridge design, bridge rehabilitation, and bridge inspection. From her engineering work, Mandy has grown proficient in structural analysis and design software, including RISA-3D, Bentley LeapBridge (CONSPAN, RCPier, and Geomath), LARSA, SIMON, RetainPro, LPile, and spColumn. Mandy served as the lead bridge engineer for the Paseo Del Norte/I-25 Design Build Project in Albuquerque, NM.

SUMMARY

Paseo del Norte Boulevard (PDN) is a main connection between the east and west sides of the Albuquerque Metropolitan area, which is divided by the Rio Grande. A highly utilized corridor, PDN offers high capacity and limited traffic lights; where PDN meets I-25, though, traffic can come to a screeching halt. A reconfigured interchange was required, and a new flyover ramp became a defining feature of the improvement project. The team negotiated complex challenges for design and construction—all magnified by the busy, urban construction area—and by using steel, the team was able to complete the design and construction ahead of schedule, within budget, and with fewer impacts to commuters.

SUCCESS WITH STEEL: THE I-25/PASEO DEL NORTE INTERCHANGE RECONSTRUCTION FLYOVER

A City Divided

The Albuquerque Metropolitan area, located in central New Mexico, is by far the most populated area in the state. The metro area is composed of Albuquerque and Rio Rancho – along with several other townships and villages. The city of Albuquerque was initially settled and developed on the east side of the Rio Grande River up to the base of the Sandia Mountains. As the population has boomed in the last quarter century, this area has become saturated and housing growth expanded over to the west side of the river.

Housing growth on the west side of the river has increased exponentially, but a majority of the metro area is employed on the east side of the river (1). This can be seen in Figure 1. Areas shown in red are areas with more housing than jobs. Areas in green contain more jobs than housing opportunities. This results in a large number of commuters going from west to east in the morning hours (across the river) and the same number traveling back in the evening. There are a limited number of bridges crossing the river, so commuter congestion is concentrated around these crossings. The river crossing with the second-highest roadway capacity and highest traffic volume is Paseo Del Norte Blvd, an access-controlled highway that carries 75,000 commuters a day across the river to Interstate 25, where they disperse throughout the east side of the city (2).

The intersection of Paseo Del Norte (PDN) and I-25 was originally built as a diamond interchange, which permitted no free-flow movement in any direction, causing significant congestion issues during the morning and evening commutes. As a result, reconstruction of this interchange has been under consideration for 15 years. However, full reconstruction of the interchange would have cost over $300 million. Funding of this magnitude could not be obtained, but action needed to be taken. The scope of a reconstruction was reconsidered to address the most immediate concern – traffic moving between the east and west sides of the river. A smaller $93 million

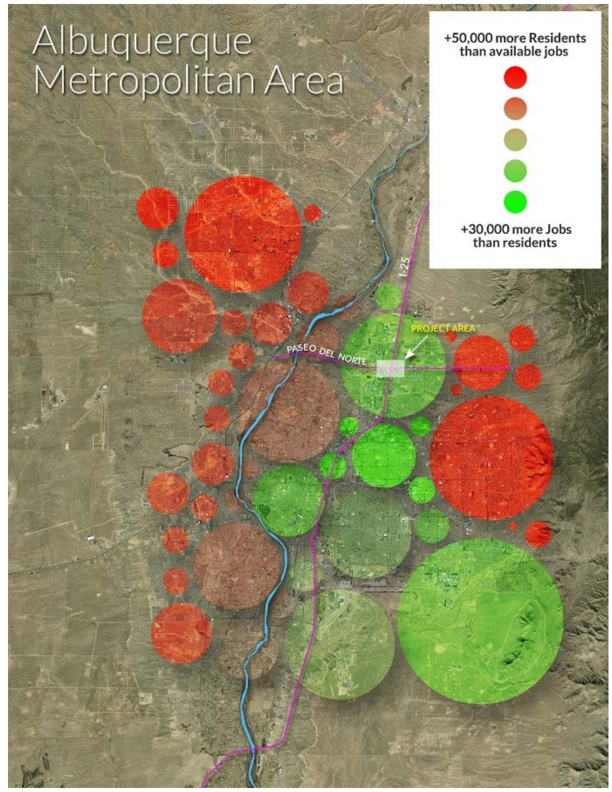

Figure 1 – Albuquerque Area Housing/Jobs Concentrations

project was developed to meet the immediate need by facilitating the continuous flow of traffic on the major commuter movements (eastbound PDN to southbound I-25 and northbound I-25 to westbound PDN).

Kiewit New Mexico, in partnership with Bohannan Huston, Inc., was awarded the design-build contract for this project. With a schedule of 16 months to go from 30% design to completion of construction, every aspect of the project was designed to be constructed efficiently. Additionally, because this was a design-build project, cost-effective designs were key to the project's success.

The Scope of the Project

At the core of this interchange project is the I-25 NB to Paseo Del Norte WB flyover ramp. The flyover had many complex challenges for design and construction – all magnified by the busy, urban area. Construction phasing required that most of the project be completed before construction of the flyover began, so it was the final piece that had to fit into a complicated puzzle – and the challenge was determining what shape the piece would take.

The flyover, as shown in Figure 2, allows traffic to move in a free-flow pattern from NB I-25 to WB PDN, greatly reducing congestion in the evening rush hour. This free-flow movement created by the flyover bridge was critical to making the interchange work. The flyover ramp, because it was located in an urban area, had significant vertical and horizontal constraints; therefore, for the Kiewit/BHI team, the choices made in designing and constructing this bridge were key to making sure the project could be delivered on time and within budget.

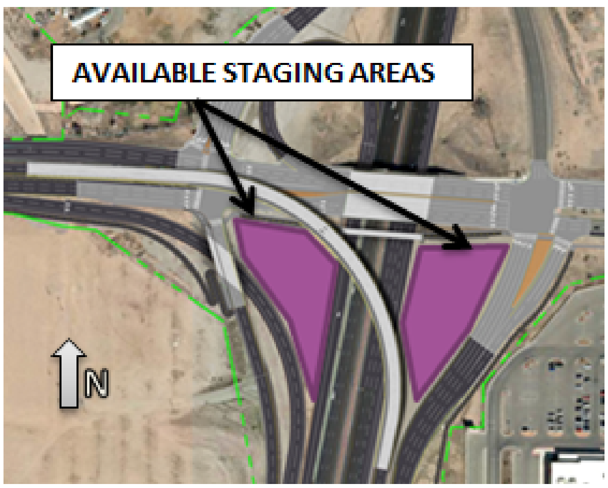

Figure 2 – Available Staging Area for Flyover Construction

Bridge Type Selection

Four main evaluation criteria were used in the bridge type selection: bridge type cost, anticipated bridge life, user delay costs, and traffic control costs. The two most cost-effective curved systems for the area were post-tensioned cast-in-place concrete tub girders and curved steel plate girders. Kiewit had experience building both of these systems in the Albuquerque area. One advantage of using concrete tub girders is a shallow superstructure. The controlling locations for underclearances, however, were at pier caps rather than at the girder. Even with the shallower superstructure of the tub girders, it would have been difficult to provide the requisite clearances at the piers without special details. Additionally, the increased traffic control requirements for the falsework and installation of these girders would have greatly increased user delay costs as well as traffic control costs. Also, this project was constructed within tight right-of-way limits in a location surrounded on all sides by businesses and homes. These constraints did not allow room for a casting yard nearby, and the staging areas were fairly small as highlighted in Figure 2. Additionally, the bridge would be placed over two of the busiest highways in Albuquerque. Two lanes of traffic had to be maintained on Paseo del Norte in each direction at all times except by special permit. Similarly, all lanes of I-25 had to remain open except under special weekend conditions. This made expedited girder placement a key part of constructing the flyover.

For reasons of staging, erection ease, user costs, and traffic control costs, continuous curved steel plate girders were chosen as the most constructible and efficient solution. The most cost-effective substructure and foundation choice was a cast-in-place hammerhead pier cap on single round pier columns, founded on a single drilled shaft.

Bridge Layout

The flyover geometry was controlled by multiple constraints, including roadway design speeds, existing underground utilities, and the existing roadway geometries.

To accommodate a minimum design speed of 40 mph, the flyover had an inside radius of 490' and a 6% cross slope. Coming north off of I-25, the grade rose at a rate of 6% to ensure clearance over both I-25 and PDN. Finally, the ramp had to tie with westbound PDN, which required an exit grade of 6%.

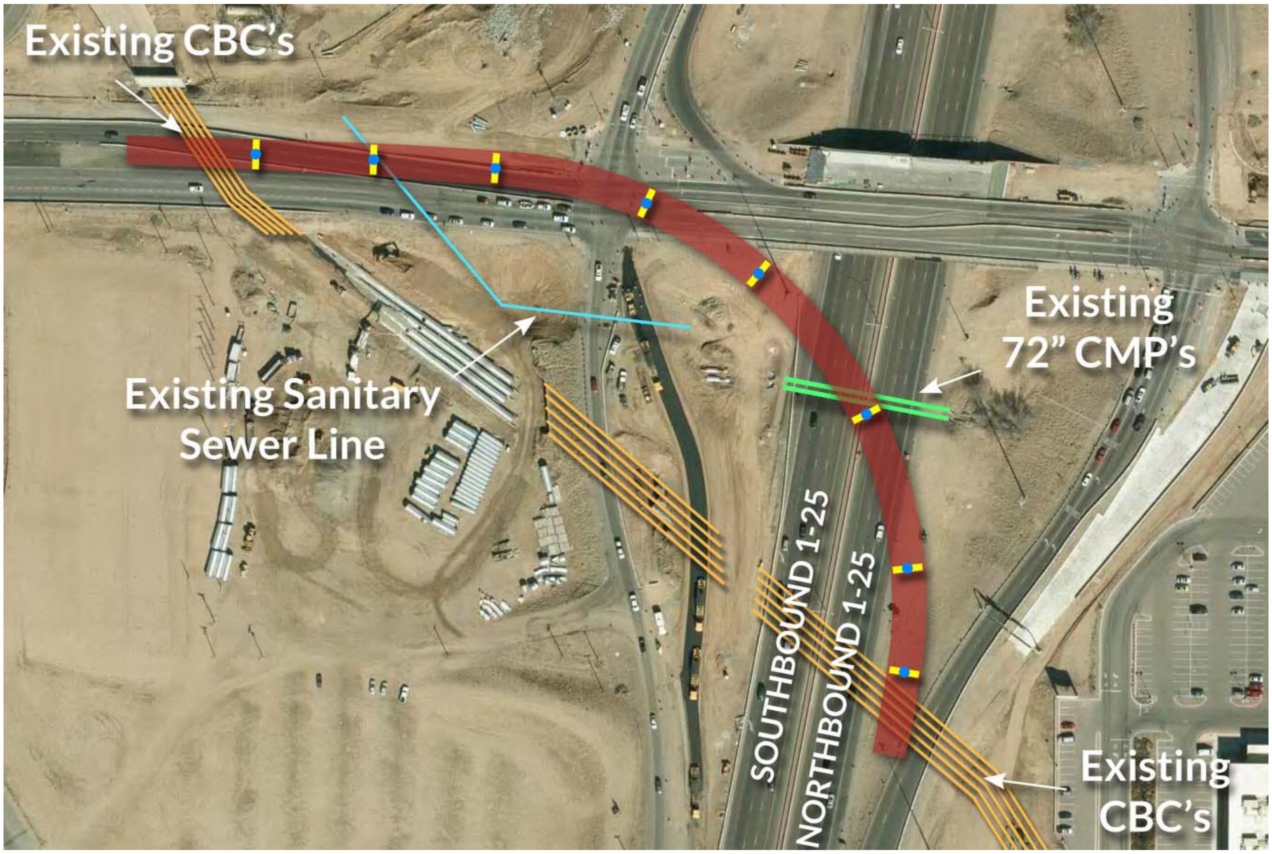

Figure 3 – Major Utilities Affecting Flyover Construction and Design.

These roadway design constraints not only drove the choice of bridge superstructure (due to the tight curvature), but horizontal curvature and vertical grade significantly constrained the flyover geometry and ultimately set the footprint for its location. With this footprint, the next challenge was determining efficient span lengths that also avoided conflicts with underground utilities and existing roadways. All of these constraints resulted in the need for several special design solutions to ensure the structure stayed out of existing roadways, avoided underground utilities, and met minimum vertical underclearances. Foundations were located to minimize the number of spans as well as avoid potential conflicts with utilities, as shown in Figure 3.

The flyover bridge comprised nine total spans: a prestressed concrete girder entrance span (100'), five spans with curved continuous steel plate girders (one at 115', three at 190', and one at 165'), and three prestressed concrete girder exit spans (123' each).

Substructure Design

Initially, it was assumed that each pier would consist of a pier cap that is 8'-6" wide x 8' deep x 41' long and a circular pier column 8' in diameter founded on 9' diameter drilled shafts. However, before full design of the substructure could begin, the substructure layout had to be finalized and accommodations made for special design needs at each pier due to site constraints from the tight vertical and horizontal constraints. Based on this evaluation, it was determined that there were four piers that required a special design – Piers 2, 3, 5, and 6. A description of each of these special circumstances follows.

Pier 2 required a relatively simple adjustment to meet vertical roadway clearance requirements. This pier cap was adjusted to have a depth of 7'-8".

As shown in Figure 4, Pier 3 had to be placed in the median of I-25 to ensure that superstructure depths stayed shallow enough to meet vertical clearances throughout the length of the structure. If the pier column and pile were placed directly in the center of the median and centered under the pier cap, the pile would have penetrated an existing 60" Corrugated Metal Pipe (CMP). Hydraulic analysis determined that the CMP could not be eliminated, and moving the pipe was cost-prohibitive. An option in which the entire pier was moved downstation was also considered. This option would reduce the driveable shoulder of NB I-25 to intolerable limits. Therefore, the final pier configuration had an eccentric pier column and drilled shaft as shown in Figure 5.

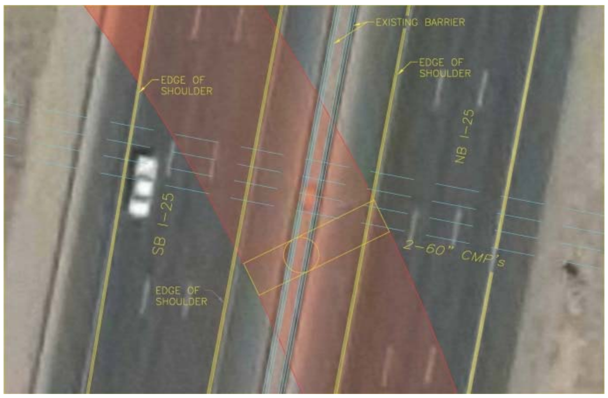

Figure 4 – Location of Pier 3 Column

Figure 5 – Pier 3 after Construction

The 5'-0" offset was to the inside curve of the bridge, moments and eccentric forces were significantly higher than if the column had been centered in the pier cap. Initially, a post-tensioned column design was considered to resist the pier forces. However, further design indicated that a 10'-0" conventionally reinforced column was adequate.

The pier cap did require post-tensioning in conjunction with conventional reinforcing to resist vertical moment forces in the pier cap. The pier cap and column were built with camber to counter the effects of short-term dead load deflections and the post-tensioning in the pier cap was relied on to counter long-term creep.

Unlike Pier 3, which only had horizontal constraints to contend with, Pier 5 had both horizontal and vertical restrictions that required special design. See Figure 6 for the plan configuration of Pier 5. The pier had a 1'-10" column offset to the outside of the curve to fit within the median of PDN. Additionally, because the pier cap was over traffic lanes, an integral pier cap was used at this location to provide adequate vertical clearances.

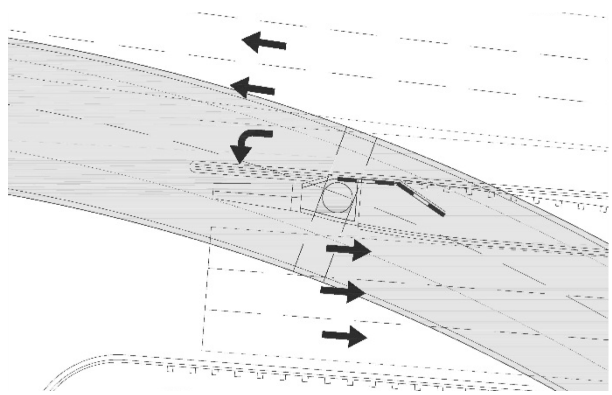

Figure 6 – Location of Pier 5 Column

As with Pier 3, both post-tensioning and mild reinforcement were used to resist moments in the integral pier cap. See Figure 7 for a visualization of the pier/girder interface and Figure 8 for a picture of the constructed pier.

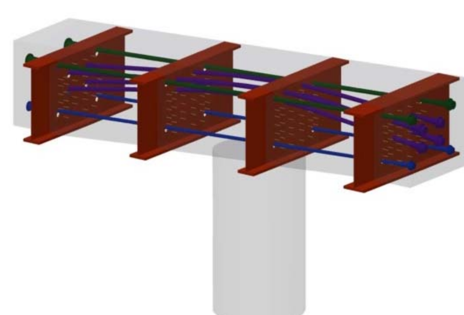

Figure 7 – Pier 5 Pier Cap Post-Tensioning Concept

Figure 8 – Pier 5 after Construction

All post-tensioned caps were also checked for stress-limit states as required by AASHTO LRFD Bridge Design Specifications (AASHTO Specifications). LARSA 4D Bridge is a finite element software for the design of advanced bridge structures. To design the stress limits in the post-tensioned caps, stress envelopes were developed using LARSA 4D and were validated against maximum allowed stresses in conformance with Chapter 5 of the AASHTO Specifications.

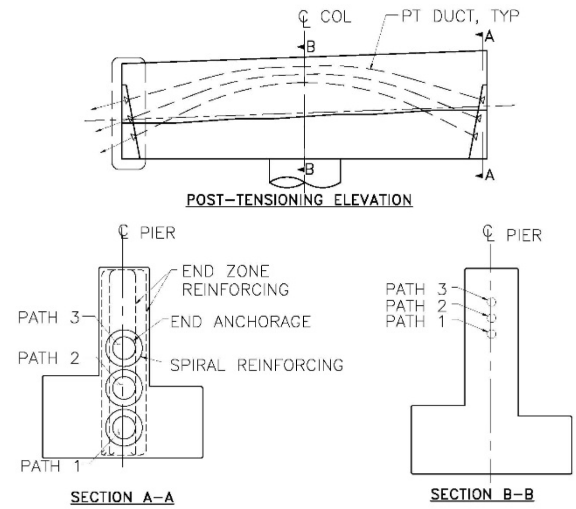

Figure 9 – Post Tensioning in Pier 6

Pier 6 also had tight vertical clearance requirements to contend with. This pier was at the end of the steel portion of the bridge, so rather than an integral cap such as was used for Pier 5, an inverted T cap was used at Pier 6. Because of the large overhang that resulted from the hammerhead pier cap, post-tensioning was again used at this location. See Figure 9 for the post-tensioning configuration that was used.

Superstructure Design

Superstructure Description

The steel portion of the flyover consisted of five continuous curved spans. As shown in Figure 10, four 78" Steel Plate Girders were used to support the superstructure.

This bridge was on a tight curve, had varying geometry, a complicated substructure, and had to be designed for NMDOT permit loads in addition to AASHTO Loads. For these reasons, a Three-Dimensional Finite Element Analysis was utilized in the design of the superstructure.

3D Finite Element Analysis

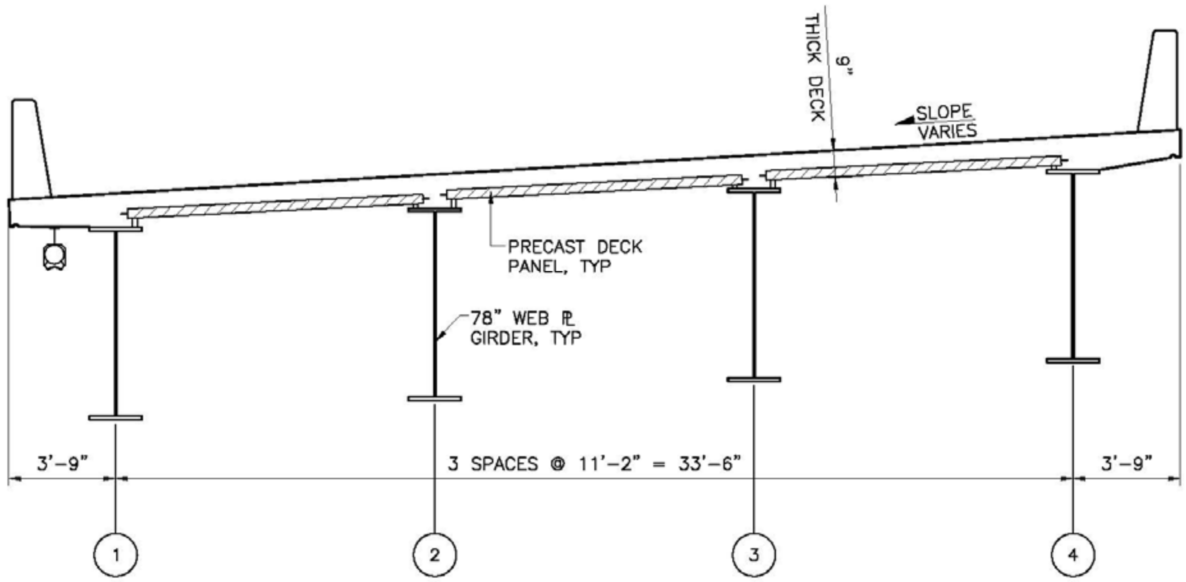

Figure 10 – Typical Section

The program LARSA 4D was used to perform the 3D finite element analysis to design the steel girders. The girder webs were modeled using plate elements, and the top and bottom flanges were modeled with beam elements. The composite deck was modeled with a series of plate elements joined to the girder top flanges via shared joints. Cross frame members were modeled with individual truss elements connected to girder nodes.

The result was a model that allowed the design team to accurately simulate various design and loading conditions.

Bearing Orientation

AASHTO LRFD Specification Article 4.6.1.2 discusses the analysis of structures curved in plan. The entire superstructure, including bearings, shall be considered as an integral structural unit. Restraint of bearings from the substructure should be considered.

Without bearing restraints, a curved girder would move laterally as well as vertically due to bending forces. With the bearing restraint in place, bearing forces can cause an arching effect that will seem to reduce the moments due to gravity loads in the beams (3). If these reduced moments are used in girder design, the bearing must function as assumed for the life of the bridge per LRFD Specifications Article C4.6.3.3.2.

Therefore, two similar superstructure finite element models were created. The first was used in the design of the gravity design of the main girder members. In this model, the lateral bearing restraints were released. The second model was used to determine cross frame forces and lateral bearing forces. In this model, lateral bearing restraints that mimicked the true bearing conditions were used.

At the ends of the bridge, guided bearings were utilized. This allowed expansion of the steel girders but ensured that the girders moved in a guided, predictable direction. At the intermediate piers, bearings were fixed in all lateral directions.

Live Load Analysis

Because live load distribution factors are not typically recommended for horizontally curved steel girders, influence surfaces were used in the live loads analysis. Three influences surfaces were created – one for vertical vehicle loading, one for centrifugal force loading, and one for braking force. Multiple presence factors and impact factors were incorporated into the analysis as appropriate.

Other Elements

Because this is a curved structure, shear connectors were provided for the entire length of the structure. The pitch of the shear connectors was calculated for fatigue and checked for the strength limit state.

In general, there are two intermediate transverse web stiffeners (where required) at even spaces between cross frame locations. This provided a minimum of 5' spacing of transverse stiffeners in high moment regions. Transverse stiffeners were incorporated into the connection plates at cross frame locations.

Cross frames were spaced at a minimum of 15' on center. They were also located near the end of field sections and at all bearing locations. Cross frames are considered primary members in a curved steel girder bridge.

Fabrication and Construction

Fabrication

Through close coordination with the girder fabricator, AFCO Steel, the steel girders were fabricated to the exact specifications of the design at one of their facilities in Arkansas as shown in Figure 12.

The girders were shipped to the site and stored in a relatively small staging area, as shown in Figure 2. Kiewit was able to prepare the girders for erection without affecting traffic movements. Crews worked around the clock installing cross frames, painting the girders, and otherwise prepping the girders to be placed on the substructure. The choice to use steel girders allowed this work on the girders to happen at the same time that work was completed on substructure elements, cutting the overall project schedule significantly.

Figure 12 – Girder Fabrication

Construction

In the month of October, right in the middle of the flyover construction, there was an added challenge to keeping the project on schedule. The Albuquerque International Balloon Fiesta is held annually in October and attracts 750,000 or more visitors each year over a 10-day span (4). Every morning during the Fiesta, up to 500 balloons take flight from the Balloon Fiesta Park. The flyover bridge was constructed directly within the main thoroughfare for people going to the Balloon Fiesta Park. The proximity of these balloons to the flyover bridge can be seen in Figure 11. It was extremely important that traffic through the interchange flow smoothly to allow the numerous

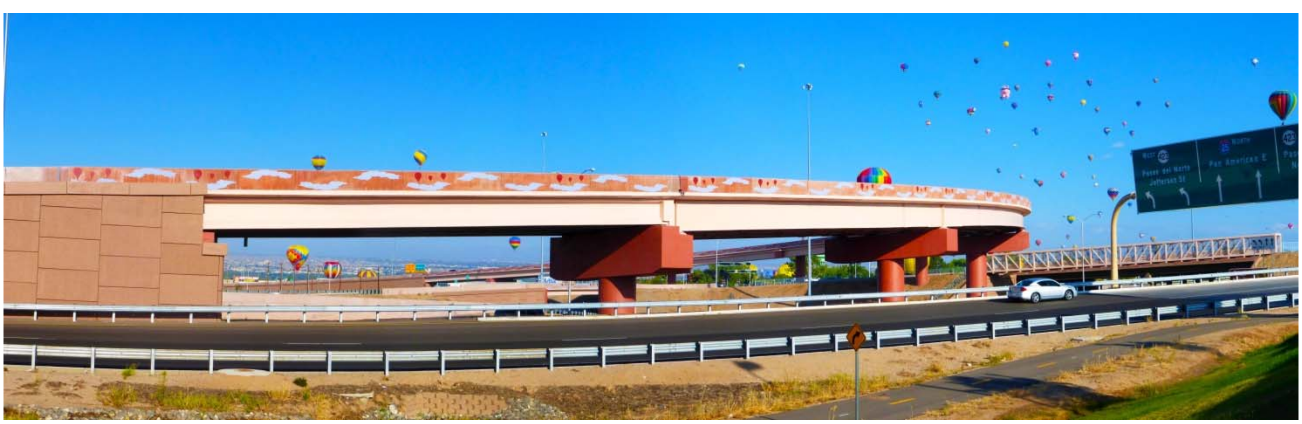

Figure 11 – Completed Flyover

visitors to enjoy the Fiesta.

For Kiewit, this meant having the steel girders placed over the interstate and out of the way before October. It also meant that traffic had to flow smoothly on Paseo Del Norte during this period. The traffic phasing limitations meant that all the substructure piers could not be completed before the Fiesta began. So work was focused on the first four piers, getting them ready so that erection of the steel girders over the interstate could be completed before the Fiesta, thereby avoiding construction over the interstate during the event. Everything went as planned, and the steel girders spanned the interstate prior to the beginning of the Fiesta.

However, this strategy created a different challenge for Kiewit. They could not wait until Piers 5 through 8 were completed before beginning work on the bridge deck. So the design and construction team developed an innovative construction sequence that allowed them to stay on schedule. There was significant schedule advantage to begin placing the partial-depth precast depth panels, overhang brackets, and deck reinforcing on Spans 1-4 before the girders in the remainder of the spans were placed – which means that they would be placed on the girders before the girders were made fully continuous as originally designed.

Kiewit Infrastructure Engineering Company (KIE CO) developed a construction phasing plan that allowed this construction sequence to be completed safely and within tolerances that did not affect the original girder design (5). They checked deflections and stresses for the girders and cross frames for each stage of erection and loading. Deflections were checked to ensure that it was feasible to complete splices between the first half of the bridge and the second half despite added loads in the first half.

Locations where the girders would be out of square due to loading were checked to ensure that the girders were manipulated properly to allow final placement of the cross frames. The stresses that were checked included flange lateral stresses, cross frame reaction, and warping torsion. It was determined that the construction sequence was feasible and that the stresses would be well below those accounted for in the original girder design, such as the non-composite stresses that would occur during the deck pour.

Once it was determined that this unusual construction sequence was feasible, Kiewit put it to work, as shown in Figure 13. They were able to complete the remaining substructure elements at the same time. Then they completed the remaining superstructure spans and appurtences and completed the construction of the bridge.

By December, 2 months after the Balloon Fiesta, ahead of schedule and less than 16 months after they were awarded the project, Kiewit opened the Paseo Del Norte Interchange to the traveling public (see Figure 14).

Figure 13 – Placement of Deck Panels Mid-Construction

Figure 14 – Aerial Near End of Construction

(1) Bureau of Business and Economic Research, University of New Mexico (2000), *Urban Growth Projections 1999-2010.*

(2) Mid-Region Council of Government of New Mexico, *2013 Traffic Flow Map for Greater Albuquerque Area.*

(3) American Association of State Highway and Transportation Officials (2003), *AASHTO Guide Specifications for Horizontally Curved Steel Girder Highway Bridges.*

(4) Rick Nathanson, Albuquerque Journal (2015), *Balloon Fiesta Attracted Over 100,000 More Visitors This Year.*