Photos: HDR and MDT

A significant steel Interstate crossing comes together over a large rail yard in Montana with minimal impact.

Over the Rails

BY DUSTIN HIROSE, PE

ONE OF THE FINAL PIECES of an Interstate puzzle has been put in place in Montana's capital city.

Administered by the Montana Department of Transportation (MDT), the project included reconstruction of a section of Interstate 15 (to increase capacity) and replacement of a pair of functionally obsolete and seismically deficient bridges that span the Montana Rail Link (MRL) rail yard, which includes 14 active tracks.

The new bridges over this busy rail yard needed to be built with minimal impact to its operations. Traffic maintenance during construction was another important element. The bridges are centered between the Cedar Street Interchange, located at the north end of the project, and Capitol Interchange at the south end of the project. This section of Interstate exhibits high volumes of traffic along with weaving movements between the closely spaced interchanges, which are less than a mile apart. With no acceptable detour routes, traffic had to be maintained on the existing bridges during construction. Furthermore, the project would take two full construction seasons to build, and it was imperative that one of the new bridges be built in the first construction season so that the interstate could be restored to two-lane, two-way traffic during the winter shutdown period.

Planning and Development

The Capitol-Cedar Interchange project is one of the final segments of an initiative that began in 2003, when an environmental impact statement was completed for the I-15 corridor through Helena. The statement documented the need for additional capacity and safety improvements throughout the corridor, resulting in opposite: The Interstate spans a major rail yard. below: The new bridges were built wide enough to accommodate a future fourth lane each.

several projects along the corridor. This segment consisted of many complexities that required a different approach to project delivery.

The roadway is on a steep grade in order to provide clearance over the rail yard in the short distance between the interchanges. Weaving movements between the interchanges, along with the relatively narrow 28-ft-wide bridges, resulted in traffic accident clusters, specifically in winter months when driving conditions were poor.

The environmental document identified the need to replace the functionally obsolete bridges and widen the roadway to add an auxiliary lane in each direction to reduce the weaving movements between the interchanges. The immediate goal was to add an auxiliary lane in each direction. However, long-term planning identified the need for an additional through lane along the corridor and within the service life of the new bridges. Therefore, the new bridges over the rail yard were built wide enough to accommodate a future fourth lane each, and the roadway drainage infrastructure was also designed and built with additional capacity to accommodate a future through lane.

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The team performed a comprehensive evaluation of the various bridge types and span arrangements and how they would impact the rail yard.

Placing deck reinforcement.

The chosen bridge span arrangement required three railroad tracks to be relocated in advance of construction.

In addition to traffic maintenance and minimizing the impact to the active rail yard, contaminated soils, oversized loads, storm water, City of Helena coordination, noise impacts and utilities routing also needed to be addressed. As such, MDT required a different approach that would serve to identify risks early on and develop strategies for mitigating them ahead of construction.

In 2010, MDT selected HDR to lead the design effort for the project, which began with a comprehensive bridge Type, Size and Location Study. Out of 23 different bridge options that were considered in all, two options stood out as providing the best fit concept for this site, a concrete option and a steel plate girder option, both calling for four spans—180-ft – 212-ft – 212-ft – 180-ft (784 ft total)—for both northbound and southbound bridges.

HDR continued with developing the project final design through a custom project schedule that allowed for an accelerated delivery due to the significant planning done during the bridge study. In the end, the steel option prevailed thanks to cost and speed. Considering the bridge skew, width of the structures, erection over the rail yard and aggressive construction schedule, the cost of the steel portion was well below the design team's original estimates (final erected cost was roughly $1.10 per lb). The final design uses around 2,000 tons of steel in all for both bridges, with the girders being approximately 6.5 ft deep and made from grade 50 weathering steel. By 2015, the project final design and right of way acquisition was complete, and the project was let to construction in 2016.

Railroad Coordination

A proactive approach to engaging the railroad early in project development was needed in order to develop a bridge design that could accommodate the needs of the highway above yet be practically built in the busy rail yard.

As part of the bridge study, the design team performed a comprehensive evaluation of the various bridge types and span arrangements and how they would impact the rail yard, and clear spanning all of the tracks was not a practical option. Intermediate bents would be necessary and properly locating them required an understanding of rail yard operations, so in addition to referencing standard railroad guidelines, input from local railroad personnel was needed to help establish final clearances between bridge elements and the railroad tracks. In addition, temporary clearances during construction, permissible track closures and acceptable construction work windows were important variables to consider when evaluating possible span configurations and were dependent on the specific operations within the rail yard.

Site access was another important consideration. Access from one end of the bridge site to the other during construction would require the contractor to cross the railroad tracks, move equipment and materials around a lengthy detour or mix with the travelling public through the Interstate construction zone, which would be restricted to two-lane, two-way traffic. On top of that, speed of construction was another crucial aspect of the project, and having the ability to stockpile materials and equipment on both ends of the rail yard would be important to avoid the inefficiencies of having to frequently cross the tracks or travel through the construction zone with equipment and materials.

The chosen bridge span arrangement required three railroad tracks to be relocated in advance of construction. It was more economical to move the tracks than to increase girder lengths and span over them. As a result, the preferred bridge alternate included a balanced and symmetrical span arrangement that reduced material costs and was easier to erect. Without the extensive early coordination with MRL to identify this option, a bridge alternate with significantly longer spans, and higher cost, would have been necessary.

In the end, the project design team developed a partnership with MRL to design the project. Many of the items typically left for the contractor to resolve were addressed early on during the design phase, resulting in reduced risk for all parties involved.

Construction Sequencing

As the Interstate corridor is located in an urban environment, options to shift the alignment were not feasible considering the impacts to properties adjacent to the highway right of way. Even if adjacent property impacts could be justified and afforded, the geometric constraints of the closely spaced interchanges made an alignment shift impractical. Therefore, the only possible way to build the project was to sequence construction such that work on one side of the Interstate could be completed while traffic was maintained on the opposite side.

Extensive traffic analysis was performed to verify that the anticipated traffic volumes could be maintained through the construction zone along with merging traffic from the interchanges without causing significant disruptions elsewhere in the system. Although the anticipated level of service during construction was not ideal, the proposed plan of having two-lane, two-way traffic during the first construction season would function. During the following season, the newly completed bridge, which is significantly wider than the previous bridges, could maintain at least one additional lane during construction. Understanding that there would be head-to-head traffic on the narrow, 28-ft wide, existing bridge during the first season, an emergency detour plan was developed in the event an accident occurred on the existing bridge.

A critical part of the project sequencing was the requirement that the first new bridge be built in the first construction season. With this requirement, the Interstate could be restored to the four-lane configuration during the icy winter months. Having traffic negotiate crossovers and traveling in a head-to-head configuration on the narrow existing bridge during the winter was not acceptable.

Considering the short, seven-month construction season in Montana along with the importance of having the first bridge complete in the first season, a detailed constructability review of the project was needed. HDR used a team of construction engineers to evaluate the project from the viewpoint of a contractor. One of the goals of the review was to understand if the bridges could be built by conventional methods within the needed timeframe, or if some type of accelerated bridge construction (ABC) method would be necessary. Although there was merit in using ABC, the cost impacts did not appear to offset the user cost benefit, and the final determination was that it would be more cost-effective to use additional equipment and workforce to complete the project using conventional methods.

Temporary shoring to support the roadway near the proposed south abutment.

Crews had to deal with the area's relatively short seven-month construction season.

A critical part of the project sequencing was the requirement that the first new bridge be built during the first construction season.

The original northbound and southbound bridges.

right: Driven steel piling was determined to be an adequate foundation type.

MDT maintains a library of historical bid prices, which are typically used to help estimate project costs. For this project, a more detailed evaluation of construction costs was performed to account for the additional equipment and work crews that were anticipated. HDR developed the cost estimate from the perspective of a contractor considering materials, equipment mobilization, labor classifications, indirect expenses and applied escalation factors for construction elements that were subject to higher risk. In the end, this exercise helped to better define the project cost. This project required a large share of MDT's construction program funding in a given fiscal year, and it was important to have a good understanding of construction cost prior to bidding the project.

Pile Test Program

Building foundations adjacent to railroad tracks typically present challenges. To name a few, there are minimum clearances to maintain during construction, requirements for shoring excavations (which can be significant if subject to surcharge loading from trains) and limited work windows available to complete the foundation construction.

HDR worked with geotechnical engineer Tetra Tech, MDT, and MRL to obtain geotechnical borings within the rail yard during the Bridge TSL work to develop options for the bridge foundations as part of evaluating various bridge alternates. Alternates with longer spans had the advantage of fewer foundation units, but generally required a larger foundation footprint compared to alternates with shorter spans.

Several soil types were encountered at the site, and a very dense matrix of cobbles and boulders was identified roughly 30 ft below the surface. The material above this layer consisted of loose fill and clay that was not ideal to support a bridge foundation. The material below this layer was relatively consistent and extended to the bottom of the geotechnical borings, which were advanced between 100 ft and 150 ft below the surface depending on the location.

Spread footings were eliminated as a practical foundation type, since the temporary shoring would be impractical to construct given the excavation depths needed to reach the dense cobble/boulder/ash soil elevation. Additionally, the bridge site is located in a moderate seismic zone, so lateral loading controlled the design of the bridge foundations. The required footprint for a spread footing, if founded at a higher elevation, was not feasible considering the close proximity of the railroad tracks. Driven steel piling were a good foundation choice considering the axial capacity that could be achieved in the cobble/boulder/ash matrix. However, there was some concern that the piling would refuse in that layer prior to obtaining enough penetration to obtain lateral fixity and the uplift capacity needed to resist seismic loading. Therefore, initial recommendations were to use drilled shafts

above: Span construction.

below: Typical intermediate cross frames.

since they could be advanced deep enough to obtain the needed capacity. The downside of using drilled shafts was that they were the most expensive foundation option, and if any defects were found during construction, they would be very difficult to correct and have significant schedule implications.

The design team recognized some significant advantages associated with a pile foundation if the piles could obtain the needed lateral capacity at the shallow depth. In addition to a significant savings in construction cost, the construction schedule could be reduced by about a month per season with a pile foundation. With this in mind, the team moved forward with a pile test program very early in the design phase of the project.

Five steel test piles were installed at the project site, and both H-piles and cylindrical piles were installed to compared drivability, capacity and penetration. As expected, most of the piles refused with minimal penetration into the cobble/boulder/ash matrix. The axial capacity obtained at this elevation was plenty adequate for the anticipated locating, and a lateral load test was performed to determine if the piles could obtain fixity and to help calibrate soil data used for analyzing the piles under lateral loading. Uplift testing was also performed for the same purpose of verifying a pile foundation would be adequate for the anticipated seismic loading. It was ultimately concluded that driven steel piling would be an adequate foundation type. The pile testing program also served to identify what equipment would be needed to install the piling during bridge construction, solidify the pile tip elevations and provide more certainty on the total length of piling needed. Additionally, the preliminary pile footprint and number of piles were reduced due to the additional capacity that was identified by the pile test program.

The program cost about $200,000 to install the test piles and perform the engineering and testing to verify the adequacy of the piles. However, compared to drilled shafts, the use of piling resulted in about $3 million in construction cost savings (total construction cost was roughly $27 million) in addition to reducing the overall construction schedule. Construction was completed last year, and the contractor, Sletten Construction, received full incentive for completing the work within the schedule requirements of the contract.

Owner
Montana Department of Transportation

General Contractor
Sletten Construction

Structural Engineer
HDR

Steel Fabricator
TrueNorth Steel AISC CERTIFIED FABRICATOR