US 6 over the BNSF Railway Bridge Replacement

Replacement Structure Alternative Analysis
Existing Structure E-17-EJ
New Structure E-17-YJ

Prepared for CDOT Region 6
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Executive Summary

Existing structure E-17-EJ carrying US 6 over the BNSF Railway is structurally deficient and will be replaced. The existing structure fails to meet minimum vertical and horizontal clearance requirements to the railroad. In order to conform to the clearance requirements the profile grade of US 6 will have to be raised. However, changes to the profile are constrained on either side of the bridge by the existing conditions. These constraints limit the structure depth available for the replacement structure.

Two feasible superstructure types, adjacent prestressed box girder and composite steel I-girder, were developed for a two-span arrangement to replace the existing structure. Preliminary design of both structure type including construction phasing was performed to develop construction cost estimates. These designs were developed in conformance with the geometric requirements provided in the *Guidelines for Railroad Grade Separation Project.* The width of the replacement structure was determined based on the preferred alignment of the *Valley Highway Environmental Impact Statement*.

The total construction cost of the two structure types is competitive, with the concrete option costing $172 per square foot, and the steel option costing $185 per square foot. Additional constructability and phasing analysis may help to select the best option.

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1.0 Existing Conditions

The existing structure F-16-EJ was originally constructed in 1956 as a set of twin structures carrying eastbound and westbound traffic over railroad lines. Subsequent widening, with additions to the interior and exterior of both bridges, created a single structure in 1967. The existing bridge is a two-span, W36 rolled steel girder with a non-composite concrete deck slab that is 130 feet long. The bridge currently carries four lanes of eastbound and four lanes of westbound traffic on US 6. See Appendix A for photographs of the existing bridge.

The west span of the bridge crosses two main line and two siding tracks of the BNSF Railway Company (BNSF). The west abutment is a tall, cantilever wall-type abutment on a spread footing while the east abutment is short, seat-type abutment founded on a combination of steel pipe and H-piles. The pier consists of several reinforced concrete columns founded in individual spread footings with a combination of hammerhead and continuous cap beams. Both the existing west abutment and the pier are located within the BNSF's right-of-way and fail to meet the minimum clearance requirements of the railroad. The current minimum horizontal clearance is approximately 9'-6" at both the west abutment and the pier. Additionally, with a current minimum vertical clearance of 22'-2", the existing bridge also fails to meet the minimum vertical clearance requirement for railroad grade separation facilities of 23'-4".

In 2009, the bridge received a sufficiency rating of 47.8 and was categorized as Structurally Deficient. The most recent Structural Inventory and Appraisal is provided in Appendix B. A temporary repair conducted in 2008 provided additional support at the southern column of the pier which is badly deteriorated.

2.0 Bridge Replacement Constraints

2.1 Railroad Clearance Requirements

To facilitate railroad approval on grade separation projects, it is generally desirable to provide minimum horizontal and vertical clearances given in the *Guidelines for Railroad Grade Separation Projects (Guidelines)*. The minimum required vertical clearance above the top of high rail to the low chord of the structure given in the *Guidelines* is 23'-4". The minimum required horizontal clearance measured perpendicular from the centerline of the track to piers or abutments located within the railroad's right-of-way is 25'-0". The *Guidelines* also suggests placing piers and abutments outside of the railroad's right-of-way whenever feasible.

It is noted that CDOT's requirement for vertical clearance over a railroad is 23'-0", or 4 inches less than the requirement of the *Guidelines*. The relative cost impact of the reduced minimum vertical clearance is likely small; however, not meeting the requirements detailed in the *Guidelines* increases the potential for delay in the railroad's approval. Therefore, the more restrictive vertical clearance requirement of the *Guidelines* was used in this analysis.

In addition to clearances for existing tracks, the *Guidelines* also requires consideration of future track alignments and maintenance roads. However, the BNSF currently has no planned projects for this area (see Field Diagnostic Meeting Minutes, Appendix C) and consequently this analysis was conducted with the current track alignment. The configuration given in this report will allow for one maintenance road on the west side within the railroad's right-of-way. There is currently no maintenance road under the existing structure.

2.2 Vertical Alignment and Available Structure Depth

In order to provide the required minimum vertical clearance of 23'-4" over the railroad, the profile grade of US 6 must be raised. Significant modifications to the profile are constrained to both the east and west along US 6 including the following:

- Located approximately 190 feet east of the existing east abutment, a gore for the westbound US 6 to eastbound I-25 ramp (Structure F-16-OL) restricts modification of the roadway profile.

- Approximately 450 feet west of the existing west abutment, a minimum under clearance of 16'-6" to Structure F-16-OL must be maintained.

- Any profile which provides adequate vertical clearance over the railroad and meets the existing constrained conditions to the east and west of the structure along US 6 will have reduced design speeds of approximately 45 mph.

These constrains from the existing roadway facilities combined with the minimum vertical clearance requirement at the railroad limit the available structure depth for the replacement bridge. Based on feasible roadway profile geometry, a maximum available structure envelope of 4'-2" was determined. However, this dimension does not account for the additional structure depth required to accommodate the roadway geometry including chording of the profile grade and superelevation transition (discussed in section 2.4), and deflection of the structure.

2.3 Roadway Width for Current and Future Alignment

The preferred system of the *Valley Highway Environmental Impact Statement (EIS)* was used to determine the required roadway width over the replacement structure. This ultimate configuration for US 6 provides for three through lanes of traffic in each direction with divergent ramps in both directions on the west side of the bridge. The replacement structure must be proportioned to accommodate the final roadway alignment while the current lane configuration on the bridge is maintained in the interim. These requirements result in a variable width superstructure on the west end of the bridge.

2.4 Superelevation Transition

The existing US 6 alignment east of the bridge requires a superelevation transition to occur within the limits of the replacement bridge. This superelevation transition will require an increased structure depth to account for the additional haunch required to accommodate the transition.

2.5 Maintenance of Traffic

During construction of the replacement bridge, two westbound lanes and four eastbound lanes must be maintained. The replacement bridge configuration needs to be capable of conforming to the phasing requirements.

3.0 Alternatives Considered

3.1 Single-Span Structure

The feasibility of a single-span structure was initially evaluated. In order to locate all substructure elements outside of the BNSF's right-of–way, a span length of 157 feet was used. Table 2.5.2.6.3-1 in the *AASHTO LRFD Bridge Design Specifications* was used to determine minimum structure depths for standard structure types constructed in Colorado. The required minimum structure depths are shown in Table 3.1. A cast-in-place structure was not evaluated because it is not feasible over the railroad.

Table 3.1—Single Span Minimum Structure Depths

Superstructure Type	Minimum Total Structure Depth
Precast Concrete I-Beams	0.045L = 7'-1"
Adjacent Concrete Box Beams	0.03L = 4'-9"
Composite Steel I-Beams	0.04L = 6'-3"

Since all of the superstructure types have a required minimum structure depth greater than the available depth of 4'-2", a single span structure is not feasible.

3.2 Two-Span Continuous Structure

Using the same overall bridge length of 157 feet for a two-span continuous structure, both abutments can be located outside the BNSF's right-of-way with a pier located to the east of the existing bridge pier with at least 25 feet of clearance to the nearest railroad track. For this arrangement, unequal spans of 109 feet and 48 feet were evaluated for the required structure depth. The required minimum structure depths for the maximum span length of 109 feet in this arrangement are given in Table 3.2.

Table 3.2—Two-Span Continuous Minimum Structure Depths

Superstructure Type	Minimum Total Structure Depth
Precast Concrete I-Beams	0.04L = 4’-4”
Adjacent Concrete Box Beams	0.025L = 2’-9”
Composite Steel I-Beams	0.032L = 3’-6”

The precast concrete I-beam (bulb tee) superstructure is not feasible because the minimum structure depth is greater than the available depth. However, both of the adjacent concrete box beam and composite steel I-beam structure types are feasible from the standpoint of minimum structure depths. A general layout for the two-span bridge arrangement is provided in Appendix D.

Preliminary designs for both the adjacent concrete box beam and composite steel I-beam structure types were completed to determine overall feasibility and cost. Both superstructure types were found to be feasible based on project constraints. Preliminary phasing for each structure type is also provided in Appendix D.

3.2.1 Adjacent Prestressed Concrete Box Girder Superstructure

An adjacent prestressed concrete box girder superstructure cross-section was developed using 25 girder lines of 34” deep by 58” wide girders with a minimum 5” cast-in-place deck slab. This superstructure has a minimum structure depth of 3’-3”. Typical sections of this superstructure type are provided on sheet B2 of the preliminary plans in Appendix D.

3.2.2 Composite Steel I Girder Superstructure

A composite steel I girder cross-section was developed consisting of 16 lines of W30x230 rolled steel girders with an 8” composite concrete deck slab. This superstructure has a minimum structure depth of 3’-8”. Typical sections of this superstructure type are provided on sheet B3 of the preliminary plans in Appendix D.

3.3 Advantages of Two-Span Structure

The two-span arrangement is advantageous because it facilitates construction, minimizes structure costs, and meets all railroad minimum clearance criteria. The location of the abutment on the east end of the structure minimizes the amount of earthwork that will be required on the existing embankment; it will also not require construction of any wall system in front of the new abutment. While a more balance span arrangement might be more efficient from a structural standpoint, any cost savings are likely to be minor and easily overcome by the additional embankment work required at the east end.

4.0 Substructure & Walls

4.1 Bridge Substructure

A letter of preliminary geotechnical recommendations was provided by Geocal, Inc. on April 1, 2011, and it is attached as Appendix E of this report. The letter recommends conventional driven steel H-pile or drilled caisson foundations. A feasible approach for the bridge substructure includes standard integral diaphragm type abutments founded on steel H-piles, with drilled caisson foundations and columns at the pier. Requirements in the *Guidelines* call for heavy construction of all substructure elements within the railroad's right-of-way. Accordingly, large columns with a minimum cross-sectional area of 30 square-feet are required at the pier.

Preliminary design of bridge foundations for both concrete and steel superstructure options were performed for cost estimating purposes.

4.2 Soil Nail Wall

Phased construction of the replacement structure will require the preservation of the existing abutment wall at the west end of the structure to retain the embankment as the new abutment is constructed behind the existing one. The final configuration of the bridge will require removal of the existing abutment wall that is located within the BNSF's right-of-way, and construction of a new wall to retain the embankment adjacent to the new abutment.

The preferred solution is to construct a soil nail wall behind the existing abutment and in front of the new abutment. The soil nail wall will be constructed after the phased construction of the replacement structure has been completed. The advantages of this type of construction include the reduced need for temporary shoring during phased construction of the replacement structure, lower overall cost, and reduced impact to rail operations since the existing adjacent Siding Track No. 1 will likely have to be taken out of service during demolition of the existing abutment. While cast-in-place retaining walls or a tall abutment are likely to be feasible, they are also likely to be significantly more expensive.

5.0 Cost and Constructability

Estimated construction costs for both feasible superstructure types are provided in Appendix F. Based on these estimates, the prestressed box girder is approximately 7% cheaper than the composite steel girder. However, it may be prudent to make the final determination of the structure type after further investigating the constructability of each with respect to the railroad's right-of-way and constraints to the project site as well as additional study of the construction phasing. The steel girder option may be easier to construct in this scenario, and possibly negate the cost advantage of the prestressed box girder calculated in the initial estimate.

Appendix A

Existing Bridge Photographs

Photograph 1 – Elevation of existing bridge looking north

Photograph 2 – Elevation of existing pier looking east