Design and Construction of the Wadsworth Boulevard LRT Bridge and Light Rail Station, Lakewood Colorado

Gregg A. Reese, PE, CE, Summit Engineering Group, Inc., Littleton, CO

ABSTRACT:

A unique precast girder bridge was designed and constructed to support two tracks of a new light rail line from downtown to Denver to Golden, Colorado. The bridge will also support the elevated LRT station and platform that will be located directly over Wadsworth Boulevard. The bridge consists of a 3 span precast bulb tee girder bridge that is spliced and post-tensioned to accommodate a shallow structure depth over Wadsworth Boulevard. The precast girders were designed using a standard CDOT 48 inch precast bulb tee that was haunched over the piers to a depth of 84" to span the 148' main span.

The bridge was designed as a Contractor Design Alternate to a steel plate girder bridge. The innovative design features include: integral interior piers that eliminated bearings, spliced post tensioned construction, with a shallow main span and a superstructure with a composite slab and platform structure which supports a signature station designed by a prominent local architect. These design features allowed the Contractor and Transit agency to realize significant cost savings during construction of this signature transit structure. The paper will describe the challenges and the solutions that were successfully implemented during construction and construction.

Keywords: Light Rail, Precast Girders, Post-tensioning, Falsework, Spliced, Erection, Design, Construction

INTRODUCTION

The Wadsworth LRT Bridge supports two rail lines of the Regional Transit District (RTD) light rail. The new bridge also supports a new station and platform that are located directly over Wadsworth Boulevard. Stairwells and an elevator rise up through the bridge deck to provide access for commuters arriving and departing from the station. A nearby parking garage is currently being constructed north of the west abutment which when completed will accommodate 1000 vehicles.

Fig. 1: LRT Bridge and Station over Wadsworth Boulevard

The bridge is part of the 12.1 mile long West Corridor expansion of the light rail system in Denver. The West Corridor, when completed, will run from Union Station in downtown Denver to the Jefferson County Government Building in Golden, CO. The rail line follows the path of the original Denver, Lakewood and Golden Railway which was originally opened for steam locomotive traffic in 1893. In 1909 the railway was converted to electrical power and was operated as a commuter trolley line until 1950 when the line was abandoned. The West Corridor is a part of the $7.9 Billion FasTracks Improvement Program which voters approved in 2004. The construction budget for the West Corridor is $707 Million. The rail lines are scheduled to be in service by May 2013.

Fig. 2: West Corridor Light Rail Line

The Wadsworth Bridge Station is one of the many stations along the line between Denver and Golden. The station and the adjacent parking structure were designed by a nationally recognized architecture firm. Coordination of the details necessary to integrate the complex needs of the rail line and station into a bridge structure spanning over a busy arterial road was one of the many design challenges of the project. When the project is complete it will provide an important connection point in the light rail system.

Fig. 3: Architects Rendering of Wadsworth Station Parking Structure

RTD hired a team of consulting engineers to prepare preliminary designs of all facets of the West Corridor prior to selecting a contractor. RTD chose to use a Construction Manager / General Contractor (CM/GC) approach to build the project. The final design of all elements was completed after selection of the CM/GC partner to allow participation of all parties in the development of the final solution. The CM/GC contract was awarded in June 2006.

The original design many of the bridges along the rail corridor utilized structural steel. During the final design process, a significant escalation in the price of structural steel occurred which led the Bridge Subcontractor to explore alternate designs of three of the new bridges along the corridor using precast concrete girder construction.

The Wadsworth Bridge was one of the bridges that the Contractor thought could be built more economically using precast concrete. Preliminary designs and cost estimates were developed in 2008. As the cost of structural steel returned to more normal levels, the Contractor determined that the precast redesign of the Wadsworth Bridge was still worth pursuing. Final design of the bridge was performed during the construction schedule and the cost of the additional design was absorbed into the construction budget. Final design of the bridge was completed in the spring of 2009. Construction of the Bridge was completed in the summer of 2010. The station was completed in early 2012.

BRIDGE CONFIGURATION

Fig. 4: Completed LRT Bridge over Wadsworth Boulevard

The total length of the bridge is 400’ between the abutments at the east and west ends. The bridge has three spans of120’, 160’ and 120’ with the main span crossing over Wadsworth Boulevard. The side spans accommodate the stairways and elevators at each end of the station which provide access to the station. A maximum structural depth of 5’-0” in the main span was necessary to accommodate the required traffic clearance over Wadsworth Boulevard. The vertical alignment was designed to minimize grades in and out of the station and the vertical distance commuters would need to travel between the elevated station platform and the parking lot. The shallow depth of structure and length of main span required the use of spliced, post tensioned construction.

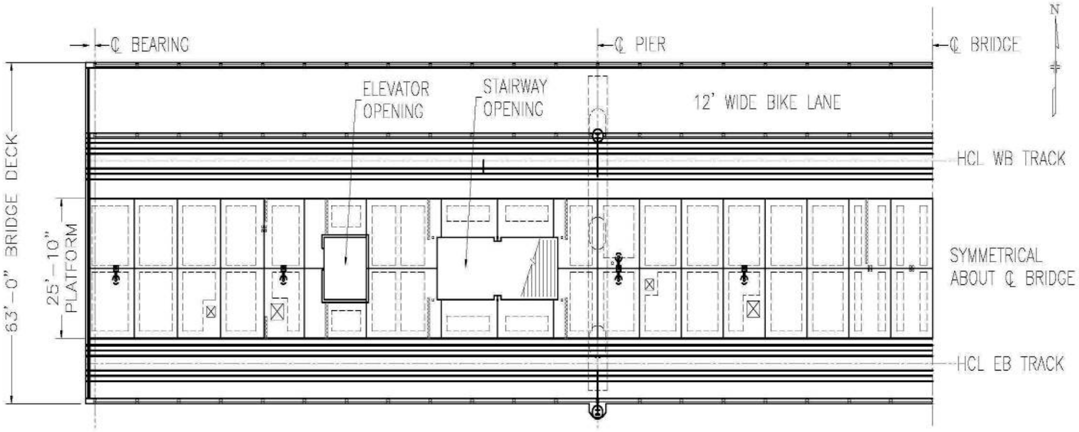

Fig. 5: Half Plan of Bridge Deck and Platform

The bridge superstructure must support two rail lines, a bike lane on the south side, the station platform and roof structure as well as provide for openings for stair and elevator access. Designing a girder layout to address all of the various loading conditions and to provide a uniform structural response that met light rail deflection criteria was the most challenging aspect of the bridge design. Girder spacings were optimized to produce a similar design load distribution for each girder line. Deck slab spans were designed for a number of different loading conditions.

SUBSTRUCTURE DESIGN

All bridges along the West Corridor utilized a project standard abutment supported on a footing and drilled shaft foundation. Girders are supported at the top of a thick cast-in-place wall pier with a back wall and wing walls on either side. The cast-in-place wing walls transition to an MSE walls on each side of the header bank approach at each end of the bridge.

The interior support consisted of three column bents with a drop cap and composite transverse diaphragm. During the design process a number of different interior bent configurations were considered. The final design that was selected provided an efficient, shallow cap that worked well with the architectural features of the piers and matched the slenderness of the bridge superstructure and the aesthetics of the station above.

Fig. 6: Elevator and Stair Access to Station through the Bridge Deck

Fig. 7: East Abutment and MSE Header Bank Approach

Each pier is 72” wide and 48” thick and is founded on a single, 60” diameter, drilled shaft with a transition cap. The piers are rigidly connected to the 54” wide x 60” deep bent cap above. Once the girders are erected, they are connected by a 30” thick diaphragm which is cast on top of the bent cap.

During erection, the pier girders were set on shoring towers at each end and on a neoprene level pad over the pier. The transverse diaphragm was cast prior to stressing longitudinal post tensioning and casting the deck slab. Only girder self weight and incidental dead loads were carried by the lower cap section during construction. The majority of all self weight, and all superimposed dead loads and live loads were designed to be carried by a composite cap/diaphragm section in the final condition.

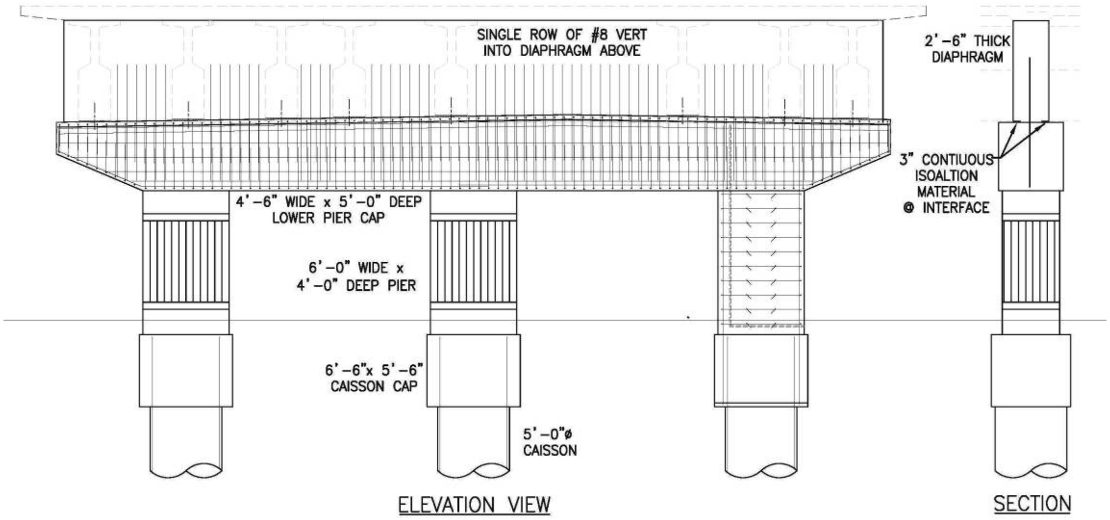

Fig. 8: Interior Bent and Lower Cap Reinforcing

A single line of vertical reinforcing was placed at the center of the interface between the cap and diaphragm. The vertical reinforcing provides the necessary horizontal shear capacity for full composite action in the transverse direction and a limited ability to develop moments in the longitudinal direction. The diaphragm is thinner than the cap below to further reduce the rotational stiffness of the connection. The perimeter of the interface between the cap and diaphragm was lined with a 3” wide compressible material to prevent spalling when the connection rotates.

The composite cap/diaphragm was designed to provide full composite action in the transverse direction and to approximate a pinned connection in the longitudinal direction. The connection eliminated the need for bearings while providing as much longitudinal flexibility as possible. Combining the effects of a longitudinally flexible foundation with a flexible connection at the interface between the substructure and superstructure produced a desirable structural response to design longitudinal movements from to temperature, elastic shortening, and long term creep and shrinkage.

Fig. 9: Completed Bridge at Interior Bent

SUPERSTRUCTURE DESIGN

As previously mentioned, the design of the bridge superstructure needed to consider a variety of different design conditions. The design needed to satisfy all service and strength design criteria and limit vertical deflections to levels required for a fixed rail transit structure with a limited structural depth.

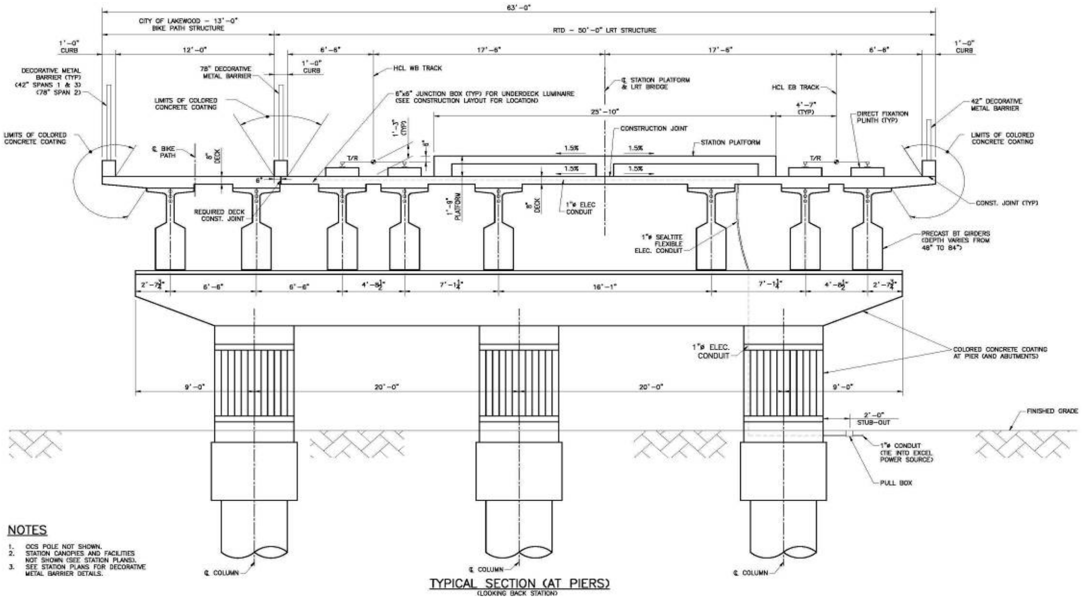

Fig. 10: Bridge Cross Section with Rail Lines, Platform and Bike Lane

The much of the challenge in the superstructure design involved balancing the design loadings on each of the girder lines to produce a more uniform response. The bridge deck will support live rail traffic, significant dead and live loads from the station and platform and a separate bicycle lane while providing the necessary openings in the deck for access. The design required a detailed analysis that considered the distribution of loadings between girders lines at various stages of construction and under service conditions as well as the potential for variability of the long term deflections of the superstructure over time.

A framing plan was developed consisting of 8 girder lines of 48” CDOT precast bulb tee girders. A variable depth section was designed over the piers with a maximum depth of 84”. A longitudinal girder layout was developed with splices at the 1/5 point of the main span to accommodate a traffic opening during construction and to maximize structural efficiency. A staged construction analysis was performed and a continuous post tensioning layout was developed with anchorages located at each end of the bridge in the abutment diaphragms.

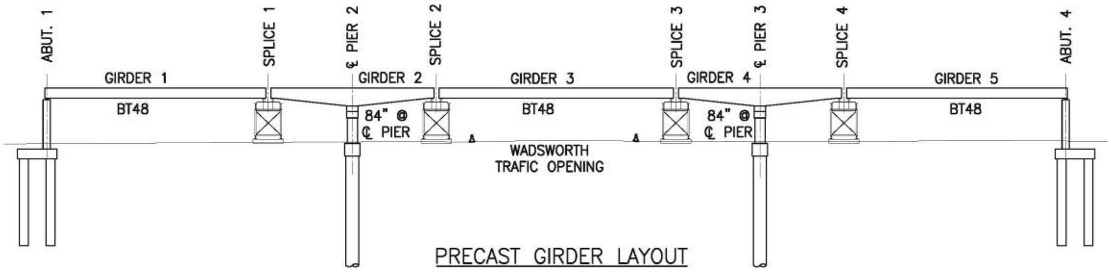

Fig. 11: Spliced Precast Girder Layout

The use of precast deck panels was not allowed for the project. The Contractor used a combination of steel, stay-in-place form and removable forms to cast the deck slab. The station platform was designed as a voided cast-in-place concrete, two way slab to distribute the various station and platform loadings to the supporting superstructure. The distribution of dead loads from the platform and the potential for differential deflections in the girders of the completed structure were significant design considerations.

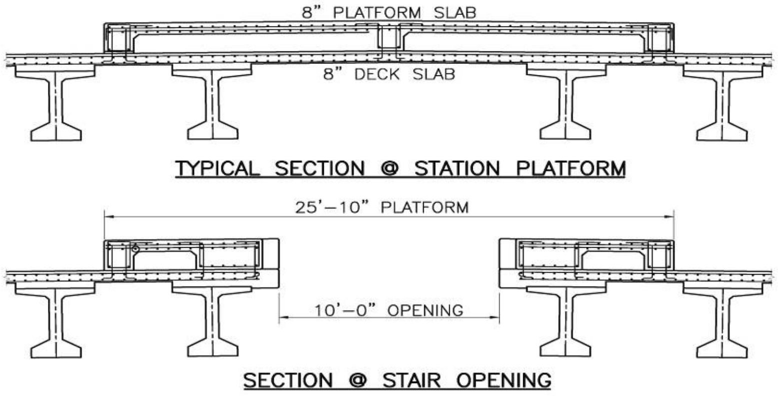

Fig. 12: Cross Section of Bridge Deck at Station Platform

A three dimensional analysis of the superstructure was performed that considered the contribution of the concrete platform to the overall stiffness of the final structure. The platform, which was cast on top of the bridge deck, was designed as a voided, two way slab. Vertical reinforcing was placed between the bridge deck and platform slab ribs that provided sufficient horizontal shear capacity to develop composite action. The transverse ribs in the voided platform slab provided excellent load distribution of dead and live loads. The platform slab was cast and cured long before the rail plinths were cast and did not affect the grading of the rail line.

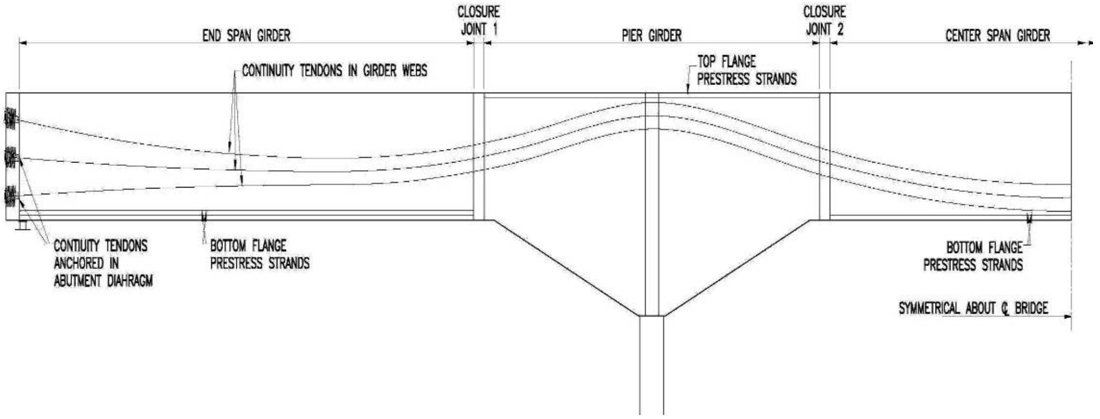

Fig. 13: Longitudinal Post Tensioning Layout

The areas of the bridge with the composite deck/platform/girder sections had additional strength and stiffness in the longitudinal direction which could support greater loads with similar deflections as the more lightly loaded areas of the bridge. Composite action between the platform and bridge superstructure resulted in comparable long term self weight load deflections in all girder lines across the bridge. This enabled the design to use a uniform post tensioning layout in all girders as well as a much greater consistency in deflections between different girder lines under permanent loadings than expected.

ERECTION OF SUPERSTRUCTURE

Fig. 14: Precast Girders on Temporary Falsework Towers

The design of the station was not finalized in the summer of 2010. For this reason the platform slab was cast until late 2010 when all of the various embedded items in the platform slab had been finalized. The rail plinths were cast in the spring of 2011. The rail lines were placed, electric lines and control systems were installed and the station construction was completed in May 2012.

Fig. 15: Final Bridge and Station Construction, April 2012

SUMMARY

The Wadsworth Bridge and Station is an important component of the West Corridor of the Light Rail System in the Denver Metro area. The precast concrete bridge design blended perfectly with the overall concept to produce a slender, elegant structure that is economical and was built well ahead of schedule. The bridge and station is a strikingly attractive architectural and technical achievement. The cooperative efforts of planners, engineers, architects and builders have produced an attractive and highly functional example of modern urban infrastructure that will serve the community well for many years to come.