STRUCTURE SELECTION REPORT

FOR

SH92 over UNION PACIFIC RAILROAD RETAINING WALLS

Project: SH92 Austin to Hotchkiss Corridor

Wall I-05-A

Wall I-05-B

Wall I-05-C

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1.0 Project Description

This project is a 14-mile segment of State Highway 92 (SH92) located between the towns of Austin and Hotchkiss in western Colorado. The project will provide an improved 2-lane roadway by reconstructing and widening SH92 to address safety concerns and improve capacity and pavement surface. As part of the improvements, a bridge will be constructed to replace an existing at-grade crossing between the road and existing Union Pacific Railroad (UPRR). Due to the high skew of the roadway alignment over the railroad and to reduce the span of the bridge over the railroad, retaining walls are proposed at each bridge abutment (East and West Walls). The walls will be constructed along the alignment of the railroad, retaining the embankment fill required for the new roadway alignment. The wall face will provide a minimum of 25 feet clearance to the centerline of the track. In addition, there will be a cut wall located approximately near SH92 station 442+00 (RW 442).

2.0 Design Criteria

Retaining Wall 442 (I-05-C)

Design Method: AASHTO Bridge Design Specifications, Sixth Edition 2012, Load and Resistance Factor Design

Assumed Wall Design Data to evaluate RW 442

Geotechnical parameters were not available for the initial submittal of this report in August of 2011. Geotechnical information was then provided by CDOT Geotechnical Program on March 12, 2012; however, the preliminary geotechnical report did not include sufficient information to revise the recommendations provided in the initial submittal. The preliminary design parameters are listed below; however boring log information necessary for determining the coefficient of friction for sliding and for confirmation of the design parameters was not available. Therefore, re-evaluation of the preliminary wall quantities was not completed. The retaining wall geometrics for wall RW 442 and the associated quantities are based on the following design parameters provided the initial submittal:

RW 442 Initial Design Parameters as of August 2011

Allowable Bearing Pressure = 2,500psf
Lateral Active Pressure = 40pcf

RW 442 Preliminary Design Parameters as of March 12, 2012

Nominal Bearing Capacity = 4,200psf (assuming the footing is founded on a 2:1 slope)
Factored Bearing Capacity = 2,310psf (resistance factor of 0.55)
Lateral Active Pressure = 35pcf
Friction Coefficient on Clay = 0.35 (assumed)

Friction Coefficient on Sand = 0.45 (assumed)

The final design parameters were provided by CDOT on April 10, 2013 as follows:

Nominal Bearing Capacity = 6,200psf (footing is not founded on a 2:1 slope)
Factored Bearing Capacity = 3,410psf (resistance factor of 0.55)
Lateral Active Pressure = 35pcf
Friction Coefficient on Clay = 0.32
Friction Coefficient on Sand = 0.40

Re-evaluation of the selected wall type based on the most recent parameters was not completed because CDOT had approved the selected wall type well before this time and it is unlikely that re-evaluation would change the conclusion.

East and West Retaining Walls (Walls I-05-A and I-05-B)

MSE Wall Internal Stability and Global Stability Design Method: AASHTO Standard Specifications for Highway Bridges, Sixteenth Edition in accordance with the CDOT Standard Worksheets for MSE Walls

MSE Wall External Stability Design Method: AASHTO Bridge Design Specifications, Sixth Edition 2012, Load and Resistance Factor Design

East and West Walls Design Parameters as of March 12, 2012

Material	Nominal Bearing Capacity (q_n)	Coefficient of Sliding Resistance (μ)
Sand/Gravel[1]	25 ksf	0.45
Sand/Gravel[2]	5 ksf	0.45
Silt/Clay	5.1 ksf	0.35
Bedrock	31 ksf	0.35[3]

[1] – Reinforcement length of 30 feet.
[2] – Reinforcement length of 6 feet.
[3] – Under dry conditions.

Factored Bearing Capacity = Nominal Bearing Capacity x Resistance factor of 0.65
Lateral Active Pressure = 35pcf

According to CDOT Geotechnical Group (Email dated March 19, 2012), further testing of the claystone bedrock revealed that the friction coefficient is closer to 0.17.

Materials

Class D Concrete:	f`c = 4,500 psi
Reinforcing Steel:	fy = 60,000 psi
	Non-epoxy coated reinforcing for RW442
	Epoxy coated reinforcing for East and West Walls

3.0 Evaluation Criteria

Cost of constructing the wall is the main criteria in selecting a wall type. Additional considerations such as constructability, maintenance, aesthetics, right-of-way and environmental factors must also be taken into account.

In discussing retaining wall types for this project, it is noted that retaining walls could be logically classified into three categories according to the basic mechanisms of retention and the source of support. Many of these walls may be used in either cut or fill situations.

Externally Stabilized System – Uses a physical structure to hold the retained soil. The stabilizing forces of this system are either mobilized through the weight of a stable structure or through the restraint provided by embedment in soil, or tieback anchorages. Examples of these types of wall system include but are not limited to:

- Cast-in-place (CIP) concrete cantilever walls
- CIP concrete counterfort walls
- Gravity walls (precast or CIP concrete)
- Caisson/Drilled shaft (secant) walls

Internally Stabilized System – This type of system involves creating a reinforced soil mass to retain the fill and resist any superimposed loads. This is done by adding reinforcement into the retained soil to form a coherent mass. These reinforcements can either be layered metal or geo-grid reinforcement installed during the bottom-up construction method, or soil anchors added into the soil mass during the top-down construction method. The reinforcement must be oriented properly and extend beyond the potential failure mass. Examples of these types of wall system include:

- Mechanically stabilized earth (MSE) walls
- Soil nail and ground anchor walls

Hybrid or Mixed System – This system combines elements of both externally and internally stabilized systems. Examples of these types of wall systems include:

- Gabion walls anchored with geo-grid or geo-fabrics
- Precast concrete cantilever walls with geo-grid or geo-fabrics
- MSE walls founded on reinforced concrete footings with deep foundations (e.g., drilled caissons, micropiles)

Hybrid wall types initially were not evaluated because they are typically costly and used at locations with certain site restrictions or geotechnical constraints that were unknown at the time of the August 2011 submittal of this report. However, based on the discussion in Sections 5.2 and 5.4, hybrid systems are now a consideration for the East and West walls.

4.0 Evaluation of Items Affecting Structure Configuration

4.1 Site Data and Constraints

The SH92 alignment will have a grade separation at the crossing of the UPRR. Retaining walls along the railroad alignment (East and West walls) will be located at each abutment to reduce the amount of roadway embankment as well as the bridge span length. The cut wall at station 442+00 (RW 442) is placed in order to not impact an existing structure to the south of the alignment.

4.2 Horizontal and Vertical Alignment

Both the East and West walls along the railroad are fill walls, retaining the roadway embankment. The walls are aligned either to follow the Union Pacific Railroad horizontal alignment or to follow the SH92 alignment located outside of the 25'-0" clear zone. Vertical alignment of the walls is based on the fill required to construct the roadway over the railroad. The West wall to the North of the railroad at Abutment 1 is approximately 470 feet long with a maximum exposed height of approximately 46 feet. The West wall to the South of the railroad (East Wall), at Abutment 4, is approximately 715 feet long with a maximum exposed height of approximately 41 feet. RW442 is a cut wall with a length of approximately 376 feet and a maximum exposed height of approximately 18 feet.

4.3 Environmental Constraints

There are no known environmental constraints at this location.

4.4 Utilities

There are only a few utilities in the vicinity of the retaining walls. There are two overhead electric lines that will run through the south end of the East Wall. These lines will have to be relocated for the construction of both the walls as well as the bridge. An existing gas line will run through the West Wall alignment, and continue through the East Wall alignment, and then runs behind the East Wall. At RW442, an underground telephone line and an underground fiber optic is located at the retaining wall alignment and will be relocated to avoid conflict with the proposed wall. An overhead electric line is in the vicinity of the wall but it is assumed at this time that it will not impact construction. No other known utilities are in the construction area.

4.5 Constructability

If the foundation material is favorable with respect to satisfying stability requirements of the AASHTO Codes, construction of the walls is fairly simple and they can be constructed in a single phase of the project, with minimal disruption to railroad service. This allows for reduced costs in building the walls. Difficulty in construction of the retaining wall alternatives will be reflected in the construction cost. However, as shown in the design data provided in Section 2.0, the geotechnical parameters are not favorable for some wall types. Constructability issues are discussed in more detail for each structure alternative in Section 5.0.

4.6 Material Type and Availability

Concrete, reinforcing steel, granular backfill and soil reinforcement are all readily available.

4.7 Architectural Requirements

There are no architectural requirements in place for the walls based on direction from CDOT.

4.8 Geology

As stated in the geotechnical report for the Bridge and the East and West Walls, "The geology consists of loose sand and gravel and stiff to very stiff clay and silt underlain by medium hard to very hard shale bedrock." The geology near RW442 consists of interbedded medium dense to very dense sand with gravel and stiff clay with sand for the soil that will be excavated for construction of the wall. Cobbles and bedrock were encountered near RW442 at roughly 20 feet and 24 feet below ground surface respectively.

5.0 Retaining Wall Type Alternatives

Feasible retaining wall types include CIP and MSE retaining walls for the fill condition. Soil nail and CIP cantilevered retaining walls were considered for the cut condition. Advantages and disadvantages of each feasible structure type alternative are summarized below.

5.1 Cast-in-Place (CIP) Retaining Walls

Cast-in-place reinforced concrete retaining walls consist of a vertical stem connecting to a shallow spread footing or a footing supported on piles. This type of wall is familiar to contractors and can be constructed to meet most site conditions and geometry. If used in a cut condition, this type of wall requires a large amount of excavation to construct the wall. Some disadvantages of using this type of wall in a cut situation include a longer construction time and sometimes temporary shoring will be required. Some disadvantages of using this type of wall in a fill situation include: very tall walls typically have a higher cost than MSE walls and a longer construction time. CIP will generally be more cost-effective than MSE for shorter wall heights in fill conditions. In addition, CIP walls generally have lower settlement than MSE walls. Counterfort CIP walls are evaluated when wall heights typically exceed 30ft.

5.2 Mechanically Stabilized Earth (MSE) Retaining Walls

This type of wall system uses metal strips or synthetic geo-grids extending into the soil behind the wall face, which creates an internally stabilized (reinforced) soil mass. Advantages of MSE walls include: easy construction by readily available contractors, they are fairly inexpensive, and they are best used for fill conditions. MSE walls require control of settlement to prevent damage to the wall facing. MSE walls have larger settlements, but are typically cheaper in higher fill situations than CIP walls.

As stated in the initial submittal of this report, MSE walls were recommended for the East and West Walls; however based on the geotechnical design parameters (provided on March 12, 2012) and preliminary stability calculations, it was determined that that a significant portion of the MSE walls would require either ground improvement or foundation augmentation (e.g., concrete footing on micropiles or drilled caissons). This is due to insufficient bearing capacity, poor resistance to sliding, and potential global instability.

5.3 Soil Nail Wall

Soil nail wall construction is considered a "top-down" construction technique allowing for stabilization of soils in cut conditions through the use of installing soil nails and shotcrete to the excavation face while excavating down to finished grade in front of the wall. A CIP concrete facing panel will be installed after the wall is completed. The advantage to this type of wall is no excavation or temporary shoring required behind the wall. The disadvantages include limited utility corridor behind the wall and limited flexibility for grade changes behind the wall.

5.4 Comparative Cost Estimate

Preliminary quantities and construction cost estimate were prepared for the selected alternative and are included here. For the two fill walls at the bridge abutments, it was determined that approximately 40ft fill walls were best suited for MSE. CIP walls were assumed to be too expensive. Cost estimates for the MSE walls are attached below. Note that the cost estimates still reflect an MSE wall founded on native soils and not MSE walls with ground improvement or foundation augmentation. Various methods for mitigating the effect of the poor soils in this area are currently under consideration which does not lend itself well to improving the accuracy of the estimate.

RW WEST MSE Wall Estimate

ITEM No.	ITEM	UNIT	QUANTITY	UNIT PRICE	AMOUNT
206	Mechanical Reinforcement of Soil	CY	13036	$20.00	$260,720
206	Structure Excavation	CY	1189	$10.00	$11,890
206	Structure Backfill (Class 1)	CY	18867	$20.00	$377,340
504	Precast Panel Facing	SF	10384	$20.00	$207,680
601	Structural Concrete Coating	SY	1156	$10.00	$11,560
TOTAL					**$869,190**

RW EAST MSE Wall Estimate

ITEM	ITEM	UNIT	QUANTITY	UNIT	AMOUNT

No.				PRICE	
206	Mechanical Reinforcement of Soil	CY	9068	$20.00	$181,360
206	Structure Excavation	CY	1106	$10.00	$11,060
206	Structure Backfill (Class 1)	CY	14074	$20.00	$281,480
504	Precast Panel Facing	SF	10799	$20.00	$215,980
601	Structural Concrete Coating	SY	1203	$10.00	$12,030
TOTAL					**$701,910**

The RW442 was evaluated for both a soil nail wall and a CIP wall. Below are the quantities and estimate associated with the wall types.

RW 442 Soil Nail Wall Estimate

ITEM No.	ITEM	UNIT	QUANTITY	UNIT PRICE	AMOUNT
504	Soil Nail Wall	SF	3544	$60.00	$212,640
601	Concrete Class D (Wall)	CY	66	$550.00	$36,300
601	Structural Concrete Coating	SY	395	$10.00	$3,950
602	Epoxy Coated Reinforcing	LB	11534	$0.85	$9,804
TOTAL					**$262,694**

RW 442 CIP Wall Estimate

ITEM No.	ITEM	UNIT	QUANTITY	UNIT PRICE	AMOUNT
206	Structure Excavation	CY	2621	$10	$26,210
206	Structure Backfill (Class 1)	CY	1856	$20	$37,120
601	Concrete Class D (Wall)	CY	271	$550	$149,050
601	Structural Concrete Coating	SY	395	$10	$3,950
602	Non- Coated Reinforcing Steel	LB	47425	$0.85	$40,311
TOTAL					**$256,641**

6.0 Recommendation

MSE Walls

During preliminary design and prior to the FIR meeting held on September 7, 2011 and the release of the Geotechnical Report dated April 27, 2012, the estimated cost of the MSE Walls was approximately $1.5 million (see Section 5.4). At the FIR, CDOT implicitly approved the present wall/bridge design. After the release of the April 27, 2012 geotechnical findings, the design team determined that the MSE walls required caisson foundations in some areas and overexcavation and backfill with Aggregate Base Course (Class 3) in other areas in order to improve bearing capacity and satisfy global stability requirements. This increased the wall cost to over $4.5 million. Although a cost comparison between walls/bridge structures is not part of the original Structure Selection Reports for the MSE Walls or the Bridge, it is anticipated that the wall cost is comparable to a bridge structure.

After discussions between the Region and Staff Bridge, it was determined that a cost comparison between walls and bridge would not benefit the project and the design should continue in its current configuration.

Wall 442

For wall RW442, it was determined that the CIP Retaining is the least expensive alternative. In addition to price, CIP walls allows for most flexibility for utilities behind the wall.

7.0 Appendix A – Preliminary Plans are included in the FOR Submittal