COLORADO
Department of Transportation

CDOT Project NO. FBR R200-266
CDOT Subaccount No. 23559

STRUCTURE ALTERNATIVES EVALUATION REPORT

Region 2 Bridge Bundle Design Build Grant Project
Preliminary Design and Procurement Support Services

Structure M-21-I

(Region 2 – US 350 MP 56.454)

Prepared for: Colorado Department of Transportation Region 2
5615 Wills Blvd.
Pueblo, CO 81008

Prepared by: Inna E. Pushkarova, PE
PushkarovaInna@StanleyGroup.com
T: 720.460.4742

Stanley Consultants

Stanley Consultants Project No. 29715
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1. EXECUTIVE SUMMARY

1.1. PROJECT DESCRIPTION

The CDOT Region 2 Bridge Bundle Design Build Project consists of the replacement of seventeen (17) rural bridges on essential highway corridors in southeastern and central Colorado. The key corridors (US 350, US 24, CO 239 and CO 9) provide rural mobility, intra- and interstate commerce, movement of agricultural products and supplies, and access to tourist destinations. The 2 other bridges are Additionally Requested Elements (AREs) in the design build project. There is a total of nineteen (19) structures bundled under this project.

This design build project is partially funded by the USDOT FHWA Competitive Highway Bridge Program grant and funds from the Colorado Bridge Enterprise (14 structures, project number 23558). The 5 additional structures are funded solely by Colorado Bridge Enterprise (project number 23559). These projects are combined to form one design-build project.

The nineteen bridges identified to be included in the 'Region 2 Bridge Bundle' were selected based on similarities in the bridge conditions, risk factors, site characteristics, and probable replacement type, with the goal of achieving economy of scale. Seventeen of the bridges being replaced are at least 80 years old. Five of the bridges are Load Restricted limiting trucking routes through major sections of the US 24 and US 350 corridors. The bundle is comprised of nine timber bridges, four concrete box culverts, one corrugated metal pipe (CMP), four concrete I-beam bridges, and one I-beam bridge with corrugated metal deck.

1.2. PURPOSE OF THE REPORT

This report presents the findings of a preliminary level multidiscipline investigation of the existing conditions of the given structure. The objective of this report is not to select a new structure type but to develop guidelines that will be addressed in the Design-Build documents and make recommendations based on the available information. The information obtained in the survey, geotechnical investigation, hydrology and hydraulics, existing utilities, and environmental investigation is discussed in this report. The study evaluates feasible structure alternatives for the site and identifies all known constrains.

1.3. STRUCTURE SELECTION PROCESS

The following criteria for comparing and evaluating the structural alternatives is discussed below and will need to be considered during design-build prosses:

- Hydraulic Opening Requirements
- Roadway alignments
- ROW Impacts
- Constructability
- Construction costs
- Maintenance
- Durability
- Traffic Control

The recommendations of the report are based on the overall consideration of all these elements as appropriate to this site and bridge.

1.4. STRUCTURE RECOMMENDATIONS

Based on the subsequent discussion, the recommended structure is a 72-ft single-span concrete girder bridge. To provide the necessary hydraulic opening, the proposed bridge will utilize side-by-side, precast concrete BX24x72 box girders. The girder size was selected using Table 5B-1 from the CDOT Bridge Design Manual. The bridge will provide the required hydraulic opening and the 7-foot vertical clearance to permit use as cattle underpass. The out-to-out bridge width will be 43'-0" to provide two 12-ft travel lanes, each with a 6-ft shoulder, 2-ft shy distance, and 1'-6" Type 9 Bridge Rail. At this location US 350 crosses the existing wash at a 30-degree skew, the bridge abutments will be oriented parallel to the channel.

The contractor may select a different structure type based on their investigation, meeting the criteria described in this report.

2. SITE DESCRIPTION AND DESIGN FEATURES

2.1. EXISTING STRUCTURE

The existing structure is a three-span, treated timber stringer bridge built in 1935, crossing a seasonal wash. The bridge is located on a tangent. Bridges built in this era were based on a CDOT Standard P-117-B-H. The bridge consists of three 22'-6" spans, has a curb-to-curb width of 25'-0" and an out-to-out deck width of 26'-0" between rails. The existing vertical clearance is approximately 7'-6". The bridge framing consists of 12 rows of 6"x20" wood stringers, each spaced at 2'-2¾". The bridge deck consists of 3"x6" wood planks.

The piers are wood piers with six (6) 12" diameter timber piles and diagonal wood bracing. Each pier cap is a 12" square wood beam. Pile spacings vary from 5'-5" to 6'-1".

The abutments consist of 12" square wood abutment caps, supported on seven (7) 12" diameter timber piles. Pile spacing at each abutment varies from 4'-8" to 5'-4". There are four (4) wood wingwalls at the existing bridge. The wingwalls are 11'-9" long and vary in height. Each wingwall is supported by three (3) 12" diameter timber piles.

The existing bridge railing is attached to the outside edge of the deck and consists of a timber rail with 6"x8"x5'-0" post and single 3"x8" rail.

The bridge is located on US 350, southwest of La Junta, at milepost 56.454. The Table 1 summarizes bridge information.

National Bridge Structure Number	M-21-I
Year Built	1935
Construction Type	Treated timber stringer
Condition Rating	Poor
Load Restricted	Yes
Bridge Length	69.2 feet
Bridge Width	26 feet
Number of spans	3
Water Crossing	Seasonal wash
ADT (2019)	500
Percent Commercial Traffic	18%

Table 1 - M-21-I Bridge Information

Photo 1 - Bridge M-21-I

The replacement of Bridge M-21-I is warranted due to its age and deteriorating conditions. Five (5) girders have checks from 5%-50% of the girder thickness. Ten (10) girders (28%) are split or have been repaired with lag bolts. Other issues include:

- Exterior girders are weathered.
- 24 piles have cracks penetrating 5%-50% of pile thickness.
- All wing walls are bowed and pushed outward.
- Guard rails are split, weathered, splintered, not approved crash tested.
- Rot, mold, water staining, and deterioration are present throughout numerous primary structural components.

Because of its condition, Bridge M-21-I is load restricted, this limit trucking routes through major sections of the US 350 corridor, a key corridor between La Junta and Trinidad and connects I-25 and US 50.

Photos 2 and 3 show repairs to the girders and conditions of the bridge overall.

Photo 2 - Abutment and Repaired Girder

Photo 3 - Girders and Piles at Pier

2.2. RIGHT OF WAY IMPACT

The existing Right-Of-Way (ROW) is located approximately 180-ft (±) from the edge of the road on the west side of the bridge and approximately 52-ft (±) on the east side of the bridge. Any alternative selected by a design-build team shall not impact the existing ROW. No permanent ROW acquisitions are planned on either side of the US 350. Temporary construction easements may be required for detour or drainage erosion control.

Fencing is located along the existing right-of-way. The fencing turns and follows the existing wash, intersecting perpendicular to the bridge, this creates a cattle underpass at the bridge.

2.3. TRAFFIC DETOUR OR SHOOFLY

Approximately 100-ft north of Bridge M-21-I County Road N intersects US 350. County Road N is a two-lane dirt road and extends only to the east of US 350.

As stated by the grant application, the US 350 roadway should not be closed for construction. Two options were investigated:

1. Phasing the construction to keep one lane open was investigated. However, due to the narrow existing roadway and wood railing keeping one lane of roadway open during construction is not recommended.
2. A two-lane shoofly is recommended and will be constructed on the west side of the existing bridge with a temporary drainage pipe placed for drainage.

2.4. UTILITIES

Stanley subcontracted with Lamb-Star Engineering to provide utility location services near the structure. Based on their investigation, the existing utilities near the structure consist of the following:

- underground CenturyLink telephone line located 70-ft east of the centerline of US 350
- overhead electric line located 44-ft west of the centerline of US 350. Just north of the bridge at County Road N the powerline crosses US 350 and follows along the east side.
- the railroad overhead communication line located 207-ft west of the centerline of US 350.

All utility lines run parallel to the existing CDOT ROW line on both sides of the bridge.

2.5. GEOTECHNICAL SUMMARY

Stanley subcontracted with Yeh and Associates, Inc. to perform the geotechnical investigation of all bridges in this project. At Bridge M-21-I one boring was made at each abutment (two total).

Two bridge borings, M-21-I-B-1 and M-21-I-B-2, were drilled by Yeh near the existing bridge, and two pavement borings, M-21-I-P-1 and M-21-I-P-2, were drilled along the existing pavement approximately 250 feet from the bridge.

The bridge borings encountered lean clays interlayered with sands and gravels overlying shale bedrock. Table 1 provides a summary of the bedrock and groundwater conditions for the bridge borings. The surface elevations, approximate bedrock depths/elevations, and approximate groundwater depths/elevations are presented to the nearest 0.5 feet. The groundwater depths and elevations are based on observations during drilling.

Boring ID	Ground Surface Elevation at Time of Drilling (feet)	Approx. Depth to Top of Competent Bedrock (feet)	Approx. Elevation to Top of Competent Bedrock (feet)	Approx. Groundwater Depth (feet)	Approx. Groundwater Elevation (feet)
M-21-I B-1	4418.5	28.5	4390.0	Not Encountered	Not Encountered
M-21-I B-2	4419.0	29.0	4390.0	Not Encountered	Not Encountered

Table 2 - Summary of Bedrock and Groundwater Conditions

2.6. HYDRAULICS SUMMARY

Federal Emergency Management Agency (FEMA) has designated the M-21-I project site as being in a FEMA Zone A. A FEMA Zone A is a Special Flood Hazard Area (SFHA) inundated by the 100-year flood. The goal of this project is to provide CDOT with viable options for the replacement of structures within Zone A floodplains that cause zero rise in the water surface elevation of the stream.

Bridge M-21-I crosses a seasonal wash which flows from southeast to northwest. There is an 8-span, 110-foot-long railroad bridge approximately 300-feet to the north, downstream of bridge M-21-I. The bridges were evaluated as a system to ensure the railroad bridge was not adversely affected by the proposed changes. Preliminary investigation found no obvious scour damage to the base of the abutments or piers.

The design flow rate at bridge M-21-I is based on the 100-year storm event. The 100-year storm flow rate is 1810 cfs. An SRH-2D model was developed at this location. The hydraulic study shows that flows at Bridge M-21-I overtop County Road N just north of the bridge site.

Proposed options were modeled using the same SRH-2D model as was used for the existing conditions. The results of the hydraulic study provide two replacement options suitable to convey the 100-year storm event flows; 1) a four-cell 20'x7' concrete box culvert or 2) a 72-foot single span bridge.

This stream is considered a low debris stream, if a bridge is selected for the proposed conveyance structure, typically 2 feet of freeboard would be required. However, the existing 100-year floodplain at M-21-I hits the existing bridge girders, and due to funding and site constraints, it is not feasible to raise the bridge above the 100-year floodplain. The proposed preliminary design will not increase this condition.

A Preliminary Hydraulic Report has been completed and can provide more information about the existing and proposed hydraulics conditions.

2.7. ENVIRONMENTAL CONCERNS

Based on field investigation performed by Stanley Consultants Environmental team, the area in the vicinity of the existing bridge is adjacent to the USFS Comanche Grassland. Impacts outside of the existing CDOT ROW are not anticipated. No wetlands or any other environmental issues have been identified at this site.

No wetlands or Waters of the US, nor USFWS regulated federally listed species have been identified at this site. However, several USFS species of concern have been identified that may require coordination with the USFS before construction.

2.8. ROADWAY FEATURES

2.8.1. Cross Section

Existing US 350 is a 2-lane roadway with two-way traffic. Both lanes are 11-ft wide with approximately 2-ft shoulders.

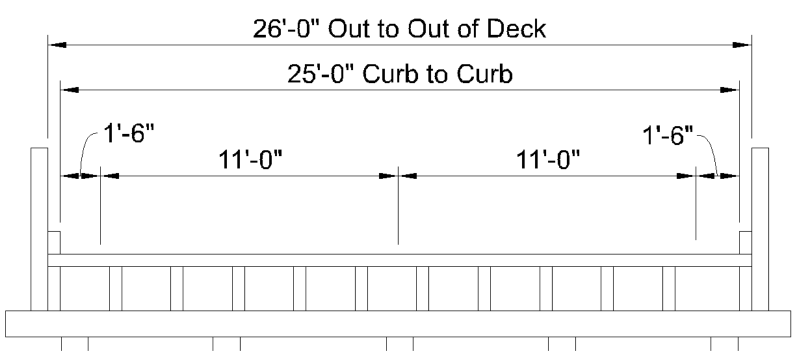


Figure 1 - Existing Roadway Section

The proposed section must be based on the requirements of the current CDOT Roadway Design Guide and on the current traffic volumes. Lane width is expected to be 12 ft in each direction with 6 ft shoulders. The ADT for this segment of road is 530 veh/day. The design speed is 75 mph. Total required roadway width over proposed structure is 40.0 ft.

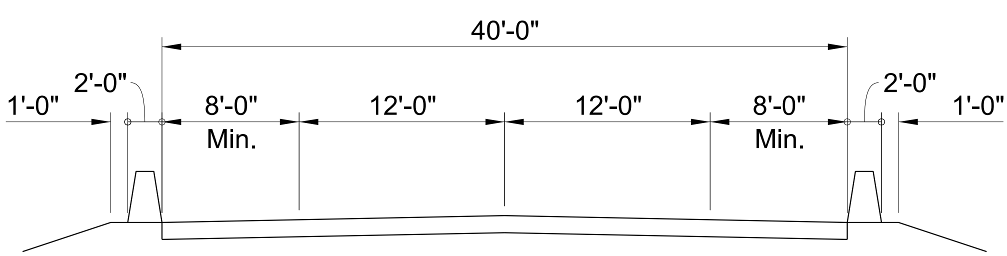


Figure 2 - Proposed Roadway Section

2.8.2. Vertical Alignment

The proposed vertical profile of US 350 must be set as close to existing as allowed by the results of the hydrology study to avoid any ROW acquisitions and to limit impacts to the existing roadway section beyond the length of the structure.

The proposed bridge profile is on a tangent with ahead station downgrade of 0.10%, practically mimicking the existing grade.

2.8.3. Horizontal Alignment

The horizontal alignment of the existing bridge has a 30-degree skew. The bridge is on a continuous horizontal tangent. It is understood that the proposed structure will be constructed in the same location as the existing with no change to the US 350 horizontal alignment

3. STRUCTURAL DESIGN CRITERIA

3.1. DESIGN SPECIFICATIONS

- AASHTO LRFD Bridge Design Specifications, 9th Edition
- CDOT LRFD Bridge Design Manual
- CDOT Bridge Rating Manual
- CDOT Bridge Detail Manual

3.2. CONSTRUCTION SPECIFICATIONS

Colorado Department of Transportation Standard Specifications for Road and Bridge Construction, 2019.

3.3. LOADING

Live Loads: HL-93 Design Truck or Tandem, Design Lane Load, Colorado Permit Vehicle

Bridge Barrier: Bridge Rail Type 10 MASH or Bridge Rail Type 9 per the CDOT standards.

Future Wearing Surface: 36.67 lbs. per square foot (3-inch minimum)

Utilities: per plan details if required at final design

Collision Load: the substructure will not require collision loading design. In cases where Bridge Rail is attached to the structure, the effects of vehicular collision on the barrier must be considered in accordance with AASHTO.

Earthquake Load: The structure is located within Seismic Zone 1 and must meet the AASHTO connection and detailing requirements.

Stream Forces and Scour Effects: stream force effects must be evaluated during final design when applicable. Possible cases include stream forces on the substructure and superstructure in addition to buoyancy from overtopping. Evaluation from scour will be performed per the CDOT Bridge Design Manual and AASHTO.

4. STRUCTURE SELECTION

4.1. SELECTION CRITERIA

The goal of this report is to identify which structural alternatives best meet the project requirements. The following criteria were established as a basis for evaluating the suitability of each structure type: hydraulic opening, constructability, construction cost, maintenance & durability, ROW and roadway impacts. The discussion below expands on these factors as it pertains to each alternative. Summary of Structure Alternatives Evaluation Table can be found at the end of Section 4.

4.2. REHABILITATION ALTERNATIVES

Rehabilitation of Bridge M-21-I will not be performed due to the age and type of the bridge. Constructed in 1935, this timber structure was in service for over 80 years and is showing signs of deterioration and aging that are inconsistent with practical and cost-effective rehabilitation.

4.3. STRUCTURE LAYOUT ALTERNATIVES

The layout of the proposed structure is controlled by the width of the proposed roadway section, stream geometry, hydraulic opening requirements and the position of the existing bridge substructure. At this location a 7-ft minimum vertical clearance is required so the crossing can be used as a cattle underpass. A 20’x7’ Concrete Box Culvert (CBC) requires an 18-in top slab thickness, the resulting clearance between the top of the box culvert and the roadway surface would be approximately 1-ft. The box will have to be designed for direct traffic load per AASHTO. A bridge alternative provides the required 7-ft vertical clearance. The bridge alternative would provide for a natural bottom which would be a benefit as a cattle underpass.

Vertical clearances over waterways were established based on hydrology and hydraulics requirements. A 6-ft minimum vertical clearance is required per the drainage report, but 7-ft was chosen to meet the criteria above.

The horizontal alignment of the proposed structure will have a 30-degree skew.

The FHWA Design of Bridge Deck Drainage, Hydraulic Engineering publications referred to by CDOT Bridge Design manual states that if the proposed vertical grade is less than 0.5%, the designer must specify a gutter grade that will run the water to the inlet boxed from high points between the boxes. As Stated in Section 2.8.2, proposed vertical roadway grade is 0.10%, matching the existing roadway profile. If a bridge structure is selected, the design team will need to address drainage issues during final design.

If the bridge structure is selected, it must satisfy the live load deflection requirement for the selected girder types specified in AASHTO LRFD Bridge Design Manual.

4.4. SUPERSTRUCTURE ALTERNATIVES

4.4.1. Concrete Box Culvert Alternative

Concrete Box Culverts (CBC) are cost-effective solutions for both the short- and long-term due to their ease of construction and maintenance. A benefit of CBC construction is they can be cast-in-place (CIP) or precast off-site and transported to the site for placement. Precast box culverts can streamline the construction process which can minimize construction duration. In addition, CBC sizes can be selected from CDOT M&S Standards that cover wide array of single-cell and multi-cell culverts.

At bridge site M-21-I a four-cell 20’x7’ reinforced concrete box culvert is required. The CBC is estimated to have a total height of 9’-10”. The box can be constructed as CIP or precast. Headwalls and wingwalls will be constructed at each end of the culvert. Due to the skew, the estimated length of the CBC is 64’-0. Per the Preliminary Hydraulic Report, it is recommended that a concrete apron be constructed between the wingwalls of the outlet with a toe wall following CDOT Standard Plan M-601-20.

4.4.2. Concrete Girder Bridge Alternative

For constructability and estimating purposes the new abutments were placed behind the existing abutments. The proposed bridge will have a span of approximately 72’-0”. To minimize the superstructure depth and meet vertical clearance requirements a shallow girder type was selected. To minimize project cost, impacts to the existing roadway profile should be avoided.

Proposed girder sizes were selected based on the CDOT Bridge Design Manual. Side-by-side 24”x72” concrete box girders were selected for the bridge superstructure. Using a 1” haunch, 5” deck and 3” asphalt the overall depth is estimated at 33”. This will provide a vertical clearance of 7.0 ft.

Cast-in-place concrete superstructures either conventionally reinforced or post-tensioned are also feasible. However, the amount of long-term shoring and falsework required for construction, potential environmental and hydraulic impacts, put this alternative at a definite disadvantage. Therefore, cast-in-place concrete bridges were removed from further evaluation.

4.4.3. Steel Girder Bridge Alternative

At this location a CIP concrete box culvert and a concrete box girder bridge alternative were evaluated. Typically, steel girders are not cost effective for short span bridges, as such they were not evaluated at this location. Steel girders also require future maintenance and are not a preferred alternative.

4.4.4. Span Configurations

Total length of the existing structure is 69’-2”. It is assumed that if the bridge alternative is selected, the proposed substructure will be constructed behind the existing abutments. Based on this assumption, the proposed bridge length will be 72’-0”.

According to information provided in CDOT Bridge Design Manual, BT, CBT and BX girders can all be used in one span configuration at this approximate length. Due to vertical clearance reasons noted above only the BX girders were considered.

4.5. SUBSTRUCTURE ALTERNATIVES

The replacement structure will consist of either a new one-span bridge or a concrete box culvert (CBC). If a bridge is selected, the abutments were assumed to be supported on driven H-pile or drilled shaft foundations. If a CBC structure is selected, the structure will be founded on shallow mat foundation. Wing walls for both bridge and CBC structures will be founded on shallow strip foundations.

An integral cast-in-place abutment supported by H-piles was selected for the preferred bridge substructure. To meet grading requirements an abutment cap will be 7.0 ft deep and 2.5 ft wide. Based on the preliminary design, abutments caps will be supported on 8 steel HP 12x53. Pile lengths were assumed to penetrate 3-5 feet into competent bedrock. Concrete wingwalls are used at each abutment.

Per preliminary hydraulic analysis this reach of the river has an aggressive river slope indicating a significant scour potential at this bridge crossing. Therefore, riprap scour countermeasures will be required, a riprap apron at each abutment and along the length of the wingwalls. The riprap slope protection at each wing wall should extend 25' from the end of the wing walls along the roadway embankment. Class 1, non-woven geotextile filter material is also recommended to be installed beneath all riprap.

4.6. ACCELERATED BRIDGE CONSTRUCTION (ABC)

CDOT has developed an Accelerated Bridge Construction (ABC) decision making process. The intent of this process is to apply ABC of some kind on most projects. Design-build team is encouraged to use these resources to evaluate cost efficiency of implementing ABC design.

4.7. CONSTRUCTION PHASING

As stated by grant application the US 350 roadway should not be closed for construction. Two options were investigated. The existing wood bridge structure does not provide adequate width to allow for a one lane phasing option.

The only option for phasing is the construction of a shoofly. Option for a one-lane and two-lane shoofly have been investigated. See traffic memorandum for details. The preferred option is a two-lane shoofly, constructed east of the existing bridge.

Refer to Section 2.3, Traffic Detour.

4.8. CONSTRUCTABILITY

Both the box culvert and bridge alternatives will require a shoofly. Constructing a box culvert would require less construction time and using precast would further reduce construction time.

4.9. MAINTENANCE AND DURABILITY

Typical CDOT specified materials and construction methods must be used for the construction of the proposed structure. Following accepted current practice in designing and constructing the structure will provide a durable bridge to meet the required 100-year service life with minimal required maintenance.

RCP pipes are not a preferred alternative due to maintenance and durability concerns. This area is subject to debris (tumbleweeds) which can clog pipes.

Concrete structures have less maintenance than steel structures and are preferred.

4.10. CORROSIVE RESISTANCE

Epoxy coated reinforcing must be used for all reinforced concrete elements. A waterproofing membrane and stone matrix asphalt will be used on top of the concrete deck or CBC to prevent water and salt intrusion.

4.11. CONSTRUCTION COST

Construction costs are one of the most important factors in the structure type selections. Preliminary construction cost estimates are prepared for all selected structure alternatives to be compared as discussed above. High level construction cost for each structure type is summarized in the table below. Detailed calculations of the cost can be found in the Appendix C of this report. Individual item costs were obtained from recent CDOT Cost Data Books. A 30% contingency multiplier was used in cost calculations.

Alternative	Construction Cost	Area	Cost ($/sf)	Cost Rating
CBC	$ 1,497,300.00	5504 sf	$ 272	1.0
Concrete Girder Bridge	$ 1,146,300.00	3096 sf	$ 370	1.3

Table 3 - Construction Cost Summary

4.12. CONCLUSIONS AND RECOMMENDATIONS

Table 4 provides a summary or feasible alternatives evaluation based on the established selection criteria.

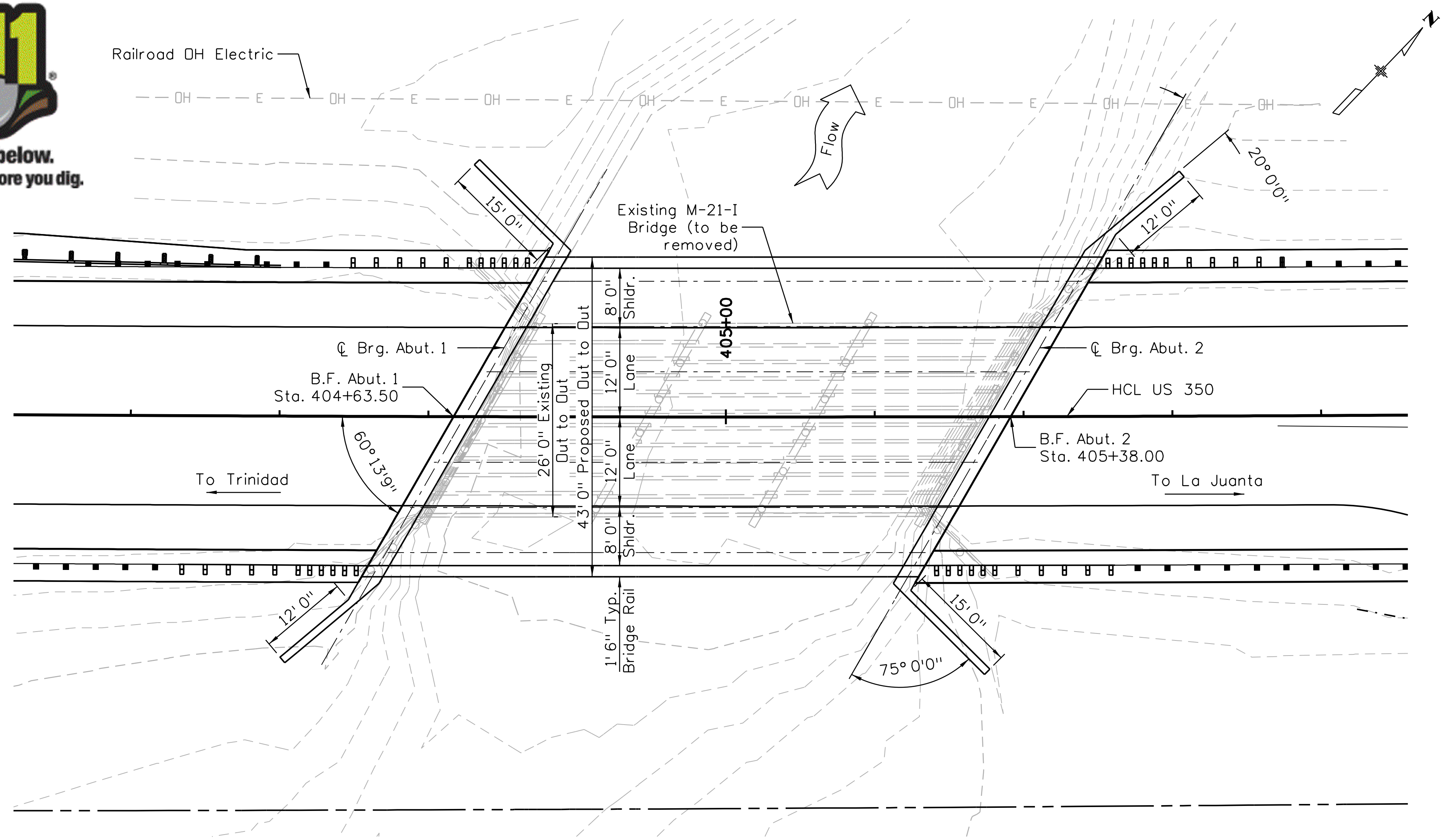
Criteria	**CBC**	**Concrete Girder Bridge**
Hydraulic Opening	Satisfies crossing requirements	Satisfies the hydraulic opening requirements. Roadway profile adjustments or other design measures required to satisfy drainage requirements.
Constructability	No expected constructability issues. Risk of storm flows during construction. Precast culvert can reduce construction time.	No expected constructability issues.
Construction Cost Rating	1.0	1.3
Maintenance & Durability	Low maintenance	Low maintenance
ROW & Roadway Impacts	No ROW impacts. Allows for cattle crossing. Provides 7-foot vertical clearance.	No ROW impacts. Natural channel better for cattle crossing. Provides 7-foot clearance.

Table 4 - Summary of Structure Alternatives Evaluation

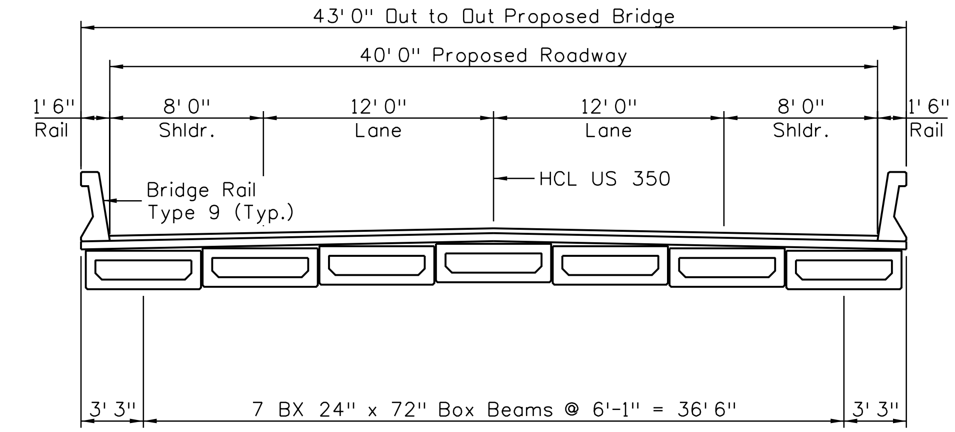
Based on the criteria discussed above, the concrete girder bridge is the recommended alternative to replace existing structure M-21-I. The contractor may select a different structure type based on their investigations, meeting the criteria described in this report. See Appendix A for the selected General Layout and Typical Section.

APPENDIX A

General Layout and Typical Section

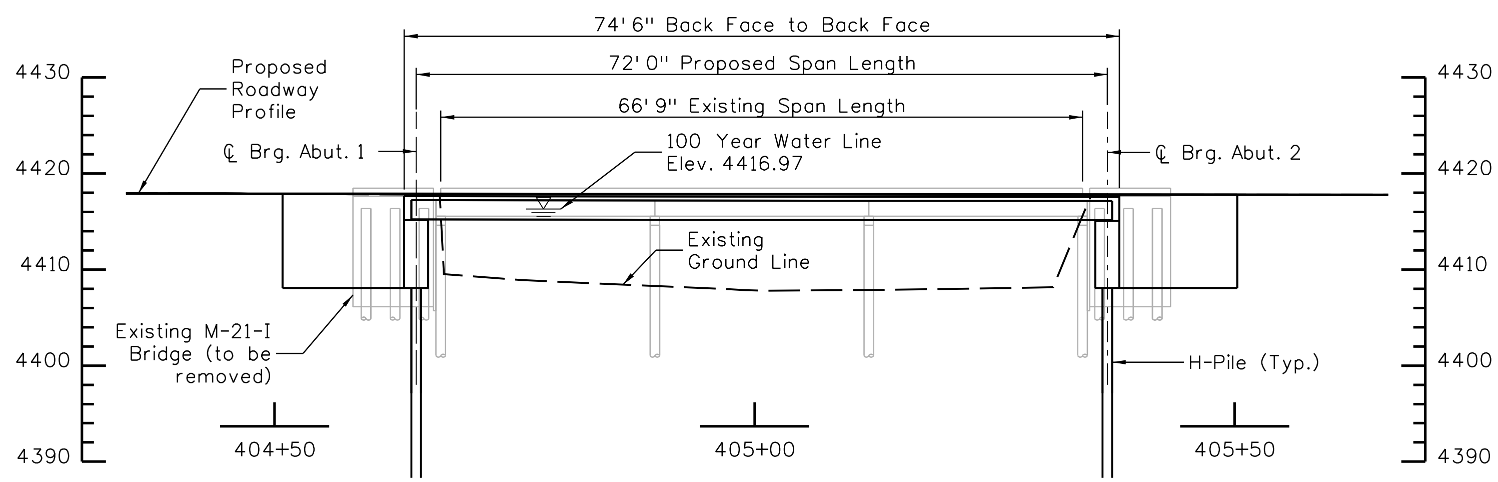


PLAN



SECTION

(Taken Normal to ℄ Bridge)



ELEVATION

(Taken Along HCL)

Notes:

1. Dimensions are based on recent survey and as-built drawings.

Print Date: 2/2/2021	File Name: 23559STR_GeneralLayout M-21-I_SH350 MP 56.45.dgn
Horiz. Scale:	Vert. Scale: As Noted

Stanley Consultants INC. 8000 South Chester St. Suite 500 Centennial, CO 80112 Phone: 303-799-6806

Sheet Revisions		
Date:	Comments	Init.

Colorado Department of Transportation

5615 Wills Blvd
Pueblo, CO 81008
Phone: 719-546-5753
FAX: 719-546-5402

Region 2 JLS

As Constructed
No Revisions:
Revised:
Void:

REGION 2 BRIDGE BUNDLE
US 350 OVER SEASONAL DRAW
GENERAL LAYOUT AND TYP. SECTION

Designer:	I. Pushkarova	Structure No.	M-21-I
Detailer:	I. Pushkarova	M.P.	US 350 56.454
Sheet Subset:	STR	Subset Sheets:	1 of 1

Project No./Code

Sheet Number

APPENDIX B

Structure Selection Report Checklist

Structure Selection Report QA Checklist

This checklist is to serve as a general guideline for structure selection process. It is to be filled out by the project Engineer of Record or designee to indicate all items that are to be discussed in the Structure Selection Report. This checklist is to be included as an appendix to the Structure Selection Report and must be signed by Staff Bridge Unit Leader or designee prior to submittal of FIR documents to the Region.

Project Name ______________________________

Project Location ______________________________

Project Number ____________________ Subaccount ____________________

Structure Number(s) ______________________________

Engineer of Record ____________________ Date ____________________

Cover Sheet

- ☐ Name of the Project and Site Address
- ☐ Structure(s) Number
- ☐ Property Owner Name and Contact Information
- ☐ Report Preparer Name and Contact Information
- ☐ Seal and Signature of the Designer
- ☐ Submittal and Revision Dates as Applicable

Executive Summary

- ☐ Project Description
- ☐ Purpose of the Report
- ☐ Structure Selection Process
- ☐ Structure Recommendations

Site Description and Design Features

- ☐ Existing Structures
- ☐ ROW Impact
- ☐ Traffic Detour
- ☐ Utilities
- ☐ Geotechnical Summary
- ☐ Hydraulics Summary
- ☐ Environmental Concerns
- ☐ Roadway Design Features
  - ☐ Cross Section
  - ☐ Vertical Alignment
  - ☐ Horizontal Alignment

Structural Design Criteria

- ☐ Design Specifications
- ☐ Construction Specifications
- ☐ Loading
  - ☐ Collision Load
  - ☐ Earthquake Load
- ☐ Software to be used by the Designer
- ☐ Software to be used by the Independent Design Checker

Structure Selection

- ☐ Selection Criteria
- ☐ Rehabilitation Alternatives
- ☐ Structure Layout Alternatives:
  - ☐ Vertical Clearances
  - ☐ Horizontal Clearances
  - ☐ Deflection
  - ☐ Skew

☐ Superstructure Alternatives:
- ☐ Concrete Girder Alternatives
- ☐ Steel Girder Alternatives
- ☐ Span Configurations

* CBC Alternative
* RCP Alternative

☐ Substructure Alternatives:
- ☐ Abutment Alternatives (GRS, Integral, Semi-integral, etc.)
- ☐ Pier Alternatives

☐ Wall Alternatives
☐ Construction Phasing
☐ Possible Future Widenings
☐ Use of Existing Bridge in Phasing / Partial Configuration
☐ ABC Design
☐ Constructability
☐ Aesthetic Design
☐ Maintenance and Durability
☐ Corrosive Resistance
☐ Load Testing Requirements
☐ Use of Lightweight Concrete
☐ Construction Cost
☐ Life Cycle Cost Analysis

Other

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Figures and Appendices

☐ Vicinity Map
☐ Alternative Typical Sections
☐ General Layout of the Selected Structure
☐ Summary of Structure Type Evaluation Table
☐ Summary of Quantities and Cost Estimate Tables
☐ Inspection Report
☐ Hydraulics Investigation Results
☐ Geotechnical Investigation Results

Recommendations

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List of Variances

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CDOT Staff Bridge Quality Assurance Sign-off

By signing this checklist Staff Bridge Unit Leader or designee acknowledges approval of the Structure Selection Report findings, recommendations, and all design deviations from the CDOT Structural Standards and design criteria.

____________________	____________________	_______________
Print Name	Signature	Date

APPENDIX C

Construction Cost Estimate

Project No.:	CDOT #23559 (Stanley #29715)	Date:	2/2/2021
Project Name:	Region 2 Bridge Bundle Design Build Grant Project		
Subject:	Quantity Calculations - M-21-I CBC Alternative		
Client:	CDOT Region 2		

CBC Alternative

Contract Item No.	Item Description	Unit	Estimated Unit Cost	TOTAL Approx Quantities	TOTAL Estimated Total Cost
202-00400	Removal of Bridge	EACH	**$ 90,000.00**	**1**	$ 90,000
206-00000	Structure Excavation	CY	**$ 20.00**	**1034**	$ 20,683
206-00100	Structure Backfill (Class 1)	CY	**$ 35.00**	**245**	$ 8,586
515-00120	Waterproofing (Membrane)	SY	**$ 22.50**	**751**	$ 16,907
601-04550	Concrete Class G	CY	**$ 900.00**	**773**	$ 695,730
601-40300	Structural Concrete Coating	SY	**$ 14.00**	**208**	$ 2,912
602-00020	Reinforcing Steel (Epoxy Coated)	LB	**$ 1.50**	**211303**	$ 316,955
				Subtotal of accounted construction items =>	$ 1,151,773
				Contingency Multiplier =>	30%
				Subtotal of construction items =>	**$ 1,497,304.65**
				Deck area (SF) =>	5504
				Cost per SF =>	**$ 272.04**

Project No.:	CDOT #23559 (Stanley #29715)	Date:	2/2/2021
Project Name:	Region 2 Bridge Bundle Design Build Grant Project		
Subject:	Quantity Calculations - M-21-I Concrete Bridge Alternative		
Client:	CDOT Region 2		

CONCRETE BRIDGE ALTERNATIVE

Contract Item No.	Item Description	Unit	Estimated Unit Cost	TOTAL	
				Approx Quantities	Estimated Total Cost
202-00400	Removal of Bridge	EACH	$ 90,000.0	1	$ 90,000
206-00000	Structure Excavation	CY	$ 20.00	666	$ 13,316
206-00100	Structure Backfill (Class 1)	CY	$ 35.00	507	$ 17,737
420-00102	Geotextile (Erosion Control) (Class 1)	SY	$ 7.00	13744	$ 96,208
502-00200	Drive Steel Piling	LF	$ 18.00	400	$ 7,200
502-00460	Pile Tip	EACH	$ 150.00	16	$ 2,400
502-02010	Dynamic Pile Test	EACH	$ 3,100.00	2	$ 6,200
502-11253	Steel Piling (HP 12x53)	LF	$ 68.00	400	$ 27,200
506-00000	Riprap	CY	$ 120.00	1140	$ 136,800
515-00120	Waterproofing (Membrane)	SY	$ 22.5	376	$ 8,453
601-04550	Concrete Class G	CY	$ 900.00	158	$ 142,024
601-40300	Structural Concrete Coating	SY	$ 14.00	392	$ 5,493
602-00000	Reinforcing Steel	LB	$ 3.72	32817	$ 122,080
606-10900	Bridge Rail Type 9	LF	$ 152.00	149	$ 22,648
618-01992	Prestressed Concrete Box (Depth Less Than 32 Inches)	SF	$ 60.00	3066	$ 183,960
				Subtotal of accounted construction items =>	$ 881,720
				Contingency Multiplier =>	30%
				Subtotal of construction items =>	$1,146,235.87
				Deck area (SF) =>	3096
				Cost per SF =>	$ 370.23

APPENDIX D

Geotechnical Report

Yeh and Associates, Inc.
Geotechnical • Geological • Construction Services

2000 Clay Street, Suite 200
Denver, CO 80211
(303) 781-9590
www.yeh-eng.com

February 2, 2021

Project No. 220-063

Mr. Ron Gibson, P.E.
Stanley Consultants
8000 South Chester Street, Suite 500
Centennial, Colorado 80112

Subject: Preliminary Geotechnical Study
Structure M-21-I
23558/23559 Region 2 Bridge Bundle
CDOT Region 2, Colorado

Dear Mr. Gibson:

This memorandum presents the results of Yeh and Associates, Inc.'s (Yeh) preliminary geotechnical engineering study for the proposed replacement of Structure M-21-I as part of the CDOT Region 2 Bridge Bundle Design-Build Project.

The CDOT Region 2 Bridge Bundle Design-Build Project consists of the replacement of a total of 19 structures bundled together as a single project. These structures are rural bridges on essential highway corridors (US 350, US 24, CO 239, and CO 9) in southeastern and central Colorado. These key corridors provide rural mobility, intra- and interstate commerce, movement of agricultural products and supplies, and access to tourist destinations. The design-build project consists of 17 bridges and two Additionally Requested Elements (ARE) structures.

This design-build project is jointly funded by the USDOT FHWA Competitive Highway Bridge Program grant (14 structures, Project No. 23558) and the Colorado Bridge Enterprise (five structures, Project No. 23559). These projects are combined to form one design-build project. The two ARE structures are part of the five bridges funded by the Colorado Bridge Enterprise.

The 19 bridges identified to be included in the Region 2 Bridge Bundle were selected based on similarities in the bridge conditions, risk factors, site characteristics, and probable replacement type, with the goal of achieving economy of scale. Seventeen of the bridges being replaced are at least 80 years old. Five of the bridges are load-restricted, limiting trucking routes through major sections of the US 24 and US 350 corridors. The bundle includes nine timber bridges, four concrete box culverts, one corrugated metal pipe (CMP), four concrete I-beam bridges, and one I-beam bridge with corrugated metal deck.

1 PROJECT UNDERSTANDING

Bridge M-21-I is part of the Region 2 Bridge Bundle project that will be delivered as a design-build project. Our preliminary geotechnical study was completed to support the 30% design level that will be included in the design build bid package. We understand the existing structure will be replaced with either a concrete box culvert (CBC) or a bridge structure. The new structure will be constructed along the current roadway alignment and existing roadway grade will be maintained. No significant cut or fills are required for construction of the proposed replacement structure.

2 SUBSURFACE CONDITIONS

Two bridge borings, M-21-I-B-1 and M-21-I-B-2, were drilled by Yeh in the vicinity of the existing bridge, and two pavement borings, M-21-I-P-1 and M-21-I-P-2, were drilled along the existing pavement approximately 250 feet from the bridge. The approximate boring locations are shown on the engineering geology sheet in Appendix A. The legend and boring logs are included in Appendix B. Laboratory test results are provided in Appendix C and are shown on the boring logs.

The bridge borings encountered lean clays overlying sands, gravels, and shale bedrock. Table 1 provides a summary of the bedrock and groundwater conditions for the bridge borings. The surface elevations, approximate bedrock depths/elevations, and approximate groundwater depths/elevations are presented to the nearest 0.5 feet. The groundwater depths and elevations are based on observations during drilling.

Table 1. Summary of Bedrock and Groundwater Conditions

Boring ID	Location[1] (Northing, Easting)	Ground Surface Elevation at Time of Drilling[1] (feet)	Approx. Depth to Top of competent Bedrock[1] (feet)	Approx. Elevation to Top of Competent Bedrock[1] (feet)	Approx. Groundwater Depth[1, 2] (feet)	Approx. Groundwater Elevation [1, 2] (feet)
M-21-I-B-1	426069.922, 500803.481	4418.5	28.5	4390.0	Not Encountered	Not Encountered
M-21-I-B-2	425997.498, 500748.668	4419.0	29.0	4390.0	Not Encountered	Not Encountered

Notes:

(1) Surface elevations, approximate bedrock depths/elevations, and approximate groundwater depths/elevations are presented to the nearest 0.5 feet. Location and elevation are provided by project surveyor.

(2) Groundwater depths and elevations are based on observations during drilling.

3 BRIDGE FOUNDATION RECOMMENDATIONS

We understand that the replacement structure will consist of either a new bridge structure or a concrete box culvert structure (CBC). If a bridge structure is selected, then the abutments and piers will be supported on driven H-piles or drilled shafts. If a CBC structure is selected, then the structure will be founded on a shallow mat foundation. Wing walls for the bridge and CBC structures will be founded on shallow strip foundations.

Based on the subsurface conditions encountered during our preliminary study, our engineering analysis, and our experience with similar projects, it is our opinion that driven H-pile and drilled shaft foundations are suitable for support of the bridge structure. Shallow foundations are suitable for support of the CBC and wing wall structures. Recommendations for the drilled shafts are presented in Section 3.2, driven H-pile recommendations are provided in Section 3.3, and CBC foundation recommendations are presented in Section 3.4.

The soil and bedrock properties were estimated from penetration resistance, material descriptions, and laboratory data. The design and construction of the foundation elements should comply with all applicable requirements and guidelines listed in AASHTO (2020) and the CDOT Standard Specifications (CDOT 2019).

3.1 Shallow Foundation Recommendations

Based on the depth to competent bedrock and the anticipated loading requirements, it is our opinion that shallow foundations are not suitable to support the bridge abutments. Bedrock is anticipated about 20 feet below the existing channel bottom and the relatively soft clays observed above the bedrock are not suitable for support of shallow foundations.

3.2 Drilled Shaft Recommendations

3.2.1 Drilled Shaft Nominal Axial Resistance

The estimated bearing resistance should be developed from the side and tip resistance in the underlying very hard bedrock. The resistance from the overburden soil should be neglected. The design approach in Abu-Hejleh et al. (2003) provides recommendations for the use of an updated Colorado SPT-based (UCSB) design method. In this design method, the nominal side and tip resistance of a drilled shaft in the sedimentary bedrock is proportional to the driven sampler penetration resistance. This approach was generally used to estimate the axial resistance in the bedrock. Based on local practice, the modified California penetration resistance is considered to be equivalent to a standard penetration test (SPT) penetration resistance, i.e. N value, in bedrock.

Table 2 contains the recommended values for the nominal side and tip resistance and corresponding bedrock elevations for drilled shafts founded in the underlying competent bedrock. The upper three feet of competent bedrock penetration shall not be used for drilled shaft resistance due to the likelihood of construction disturbance and possible additional weathering. To account for axial group effects, the minimum spacing requirements between drilled shafts should be three diameters from center-to-center.

Table 2. Recommended Drilled Shaft Axial Resistance

Reference Boring	Approximate Top of Competent Bedrock Elevation (feet)	Tip Resistance (ksf)		Side Resistance, (ksf)	
		Nominal	Factored (Φ=0.5)	Nominal	Factored (Φ=0.45)
M-21-I-B-1	4390.0	150	75	15	6.8
M-21-I-B-2	4390.0	120	60	13	5.9

3.2.2 Drilled Shaft Lateral Resistance

The input parameters provided in Table 3 are recommended for use with the computer program LPILE to develop the soil models used to evaluate the drilled shaft response to lateral loading. Table 3 provides the estimated values associated with the soil types encountered in the borings. They can also be used for driven H-piles, which will be described in Section 3.3. The nature and type of loading should be considered carefully. Individual soil layers and their extent can be averaged or distinguished by referring to the boring logs at the locations of the proposed bridge. The soils and/or bedrock materials prone to future disturbance, such as from utility excavations or frost heave, should be neglected in the lateral load analyses to the depth of disturbance, which may require more than but should not be less than three feet.

Recommendations for p-y multiplier values (P_m values) to account for the reduction in lateral capacity due to group effects are provided in Section 10.7.3.12 of AASHTO (2020). The P_m value will depend on the direction of the applied load, center-to-center spacing, and location of the foundation element within the group.

Table 3. LPILE Parameters

Soil Type	LPILE Soil Criteria	Effective Unit Weight (pcf)		Friction Angle, (deg.)	Undrained Cohesion, (psf)	Strain Factor, ε50	p-y modulus kstatic (pci)	
		AGT[1]	BGT[2]				AGT[1]	BGT[2]
Class 1 Structure Backfill	Sand (Reese)	130	67.5	34	-	-	90	60
Fill Clay	Stiff Clay[3] (Reese)	115	52.5	-	400	0.01	-	-
Native Clay	Stiff Clay[3] (Reese)	120	57.5	-	1,000	0.007	-	-
Native Silty Sand, Gravel	Sand (Reese)	125	62.5	33	-	-	90	60
Shale Bedrock	Stiff Clay w/o Free Water (Reese)	130	130	-	8,000	0.004	-	-

Note: [1]Above Groundwater Table
[2]Below Groundwater Table
[3]Stiff Clay w/ Free Water (Reese) for clay below groundwater table and Stiff Clay w/o Free Water (Reese) for clay above groundwater

3.2.3 General Drilled Shaft Recommendations

The following recommendations can be used in the design and construction of the drilled shafts.

1. Groundwater and potentially caving soils may be encountered during drilling depending on the time of year and location. The Contractor shall construct the drilled shafts using means and methods that maintain a stable hole.
2. Bedrock may be very hard at various elevations. The contractor should mobilize equipment of sufficient size and operating condition to achieve the required design bedrock penetration.
3. Drilled shaft construction shall not disturb previously installed drilled shafts. The drilled shaft concrete should have sufficient time to cure before construction on a drilled shaft within three shaft diameters (center to center spacing) begins to prevent interaction between shafts during excavation and concrete placement.
4. Based on the results of the field investigation and experience with similar properly constructed drilled shaft foundations, it is estimated that foundation settlement will be less than approximately ½ inch when designed according to the criteria presented in this report.
5. A representative of the Contractor's engineer should observe drilled shaft installation operations on a full-time basis.

3.3 Driven H-Pile Recommendations

3.3.1 Driven H-Pile Axial Resistance

Steel H-piles driven into bedrock may be designed for a nominal axial resistance equal to 32 kips per square inch (ksi) multiplied by the cross-sectional area of the pile for piles composed of Grade 50 ksi steel for use with LRFD Strength Limit State design. Piles should be driven to refusal into the underlying bedrock as defined in Section 502.05 of CDOT (2019). A wave equation analysis using the Contractor's pile driving equipment is necessary to estimate pile drivability.

3.3.2 Driven H-Pile Axial Resistance Factors

Assuming a pile driving analyzer (PDA) is used to monitor pile driving per Section 502 of CDOT (2019), a resistance factor of 0.65 may be used per AASHTO (2020) Table 10.5.5.2.3-1. Section 502.05 of CDOT (2019) stipulates that if PDA is used, a minimum of one PDA per bridge bent be performed to determine the condition of the pile, efficiency of the hammer, static bearing resistance of the pile, and to establish pile driving criteria. Per AASHTO (2020) recommendations, a resistance factor of 0.5 can be used for wave equation analysis only without pile dynamic measurements such as PDA monitoring. Per AASHTO (2020) recommendations, a resistance factor of 0.75 may be used if a successful static load test is conducted per site condition.

3.3.3 Driven H-Pile Lateral Resistance

The information provided previously in Section 3.2.2 may be used to evaluate H-pile lateral resistance.

3.3.4 General Driven H-Pile Recommendations

The following recommendations are for the design and construction of driven H-piles.

1. Based on the results of the field exploration and our experience with similar properly constructed driven pile foundations, it is estimated that settlement will be less than approximately ½ inch when designed according to the criteria presented in this report.
2. A minimum spacing requirement for the piles should be three diameters (equivalent) center to center.
3. Driven piles should be driven with protective cast steel pile points or equivalent to provide better pile tip seating and to prevent potential damage from coarse soil particles, which may be present at the site.
4. A qualified representative of the Contractor's engineer should observe pile-driving activities on a full-time basis. Piles should be observed and checked for crimping, buckling, and alignment. A record should be kept of embedment depths and penetration resistances for each pile.
5. It is estimated that the piles will penetrate approximately 3 to 5 feet into competent bedrock (see Table 1 for the estimated elevation for the top of competent bedrock). The final tip elevations will depend on bedrock conditions encountered during driving.
6. If the pile penetration extends below the estimated pile penetration into bedrock by 10 feet or more, the pile driving operations should be temporarily suspended for dynamic monitoring with PDA. We recommend that the subject pile be allowed to rest overnight or longer before restriking and monitoring the beginning-of-restrike with a PDA. The data collected with the PDA shall then be reduced using the software CAPWAP to determine the final nominal pile resistance. The pile driving criteria may be modified by CDOT's or the Contractor's engineer based on the PDA/CAPWAP results.

3.4 CBC Foundation Recommendations

To assure adequate foundation support and to minimize the potential for differential settlement, we recommend that the exposed subgrade soils should be scarified a minimum of 6 inches, moisture conditioned, and re-compacted in accordance with Section 203.07 of the CDOT Standard Specifications (2019) before the placement of structural elements or structural backfill. If unsuitable or soft materials are encountered after the excavation, the materials may be removed and replaced with CDOT Class 1 Structure Backfill in accordance with Section 203.07 of the CDOT Standard Specifications (2019).

Visual inspection of the foundation excavations should be performed by a qualified representative of the Geotechnical Engineer of record to identify the quality of the foundation materials prior to placement of backfill and the CBC. Groundwater may be encountered during excavation for the subgrade preparation. Groundwater control systems may be required to prevent seepage migrating into the construction zone by creating groundwater cut-off and/or dewatering systems.

The recommended nominal bearing resistance using Strength Limit State for the CBC and associated wing walls for both moist and saturated conditions are provided in Table 4. We assume the materials in contact with the bottom of the proposed CBC and wing walls will consist of native clay soils or CDOT Class 1 Structure Backfill placed in accordance with Section 203.07 of the CDOT Standard Specifications (2019). The reduced footing width due to eccentricity can be calculated based on the recommendations in Sections 11.6.3.2 and 11.10.5.4 of AASHTO (2020). A bearing resistance factor of 0.45 may be used for shallow foundations based on the recommendations in Table 10.5.5.2.2-1 of AASHTO (2020).

Table 4. Bearing Resistance for CBC and Wing Walls on Shallow Foundation

Soil Conditions	Nominal Bearing Resistance (ksf) [1, 2]
Moist	1.8 + 0.8 * B’
Saturated	0.9 + 0.4 * B’

[1] B’ is the footing width in feet reduced for eccentricity (e). B’ = B - 2e, where B is the nominal foundation width.
[2] The calculated nominal bearing resistance is based on a minimum 12 inches of embedment and shall be limited to 10 ksf.

The proposed CBC will be at the location of the existing CBC, and as needed, a portion of the CBC will be in a cut area, therefore it is estimated that the total settlement of the structure will be minimal and will occur during construction. The structure settlement is partially controlled by the weight of the adjacent embankment fill. Thus, it is recommended that the embankment fill on both sides of the CBC be placed at a relatively uniform elevation.

Resistance to sliding at the bottom of foundations can be calculated based on a coefficient of friction at the interface between the pre-cast concrete and the existing native soils or compacted CDOT Class 1 Structure Backfill. The recommended nominal coefficients of friction and the corresponding resistance factors for Class 1 Structure Backfill and native soils are provided in Table 5.

Table 5. Coefficients of Friction for CBC and Wing Walls on Shallow Foundation

Foundation Soil Type	Coefficient of Friction	Resistance Factor
Class 1 Structure Backfill	0.53	0.9
Clay	0.29	0.8

Backfill adjacent to the CBC and wing walls should be Class 1 Structure Backfill, compacted with moisture density control. Backfill materials shall have a Class 0 for severity of sulfate exposure. Fill should be tested for severity of sulfate exposure prior to acceptance.

The passive pressure against the sides of the foundation is typically ignored; however, passive resistance can be used if long-term protection from disturbance, such as frost heave, future excavations, etc., is assured. Table 6 presents recommendations for the passive soil resistances for the encountered soil conditions. The passive resistance estimates are calculated from Figure 3.11.5.4-1 in AASHTO (2020) where a portion of the slip surface is modeled as a logarithmic spiral, the backslope is horizontal and the passive soil/concrete interface friction angle is equal to 60 percent of the soil's friction angle.

The recommended passive earth pressure resistances are presented in terms of an equivalent fluid unit weight for moist and saturated conditions. The recommended passive earth pressure values assume mobilization of the nominal soil/concrete foundation interface shear strength. A suitable resistance factor should be included in the design to limit the strain, which will occur at the nominal shear strength, particularly in the case of passive resistance. The resultant passive earth force, calculated from the equivalent fluid unit weight, should be applied at a point located 1/3 of the height of the soil (in contact with the foundation) above the base of the foundation, directed upward at an angle of 20 degrees from the horizontal.

Table 6. Passive Soil Resistance for CBC

	Soil Type	Nominal Resistance	Resistance Factor
Passive Soil Resistance	Moist	319 pcf	0.50
	Saturated	153 pcf	0.50

3.5 Lateral Earth Pressures

External loads used in the analyses of the bridge abutments and wing walls should include earth pressure loads, traffic loads, and any other potential surcharge loads. Typical drainage details consisting of inlets near the abutments, geocomposite strip drains, and perforated pipes shall be included in the design to properly contain and transfer surface and subsurface water without saturating the soil around the abutments.

All abutment and wing wall backfill materials should meet the requirements for CDOT Structure Backfill Class 1 in accordance with CDOT (2019). All backfill adjacent to the abutments and walls shall be placed and compacted in accordance with CDOT (2019). It is recommended that compaction of backfill materials be observed and evaluated by an experienced Contractor's engineer or Contractor's engineer's representative.

A lateral wall movement or rotation of approximately 0.1 to 0.2 percent of the wall height may be required to mobilize active earth pressure for the recommended backfill materials. If the estimated wall movement is less than this amount, an at-rest soil pressure should be used in design. In order to mobilize passive earth pressure, lateral wall movement or rotation of approximately 1.0 to 2.0 percent of the wall height may be required for the recommended backfill materials. It should be carefully considered if this amount of movement can be accepted before passive earth pressure is used in the design.

Earth pressure loading within and along the back of the bridge abutments and wing walls shall be controlled by the structural backfill. We recommend that active, at-rest, and passive lateral earth pressures used for the design of the structures be based on an effective angle of internal friction of 34 degrees, and a unit weight of 135 pounds per cubic foot (pcf) for CDOT Structure Backfill Class 1. The following can be used for design assuming a horizontal backslope:

- Active earth pressure coefficient (k_a) of 0.28
- Passive earth pressure coefficient (k_p) of 3.53
- At-rest earth pressure coefficient (k_0) of 0.44

Lateral earth pressures for a non-horizontal backslope can be estimated using section 3.11 in AASHTO (2020).

3.6 Bridge Scour Parameters

A bulk sample of the creek bed soils/rock below the existing bridge was collected for gradation analysis. The results of the grain size analysis are presented in Appendix C.

4 BRIDGE APPROACH PAVEMENT

Pavement borings were located approximately 250 feet beyond the existing bridge abutments on each side. Prior to drilling, the existing pavement was cored with a 4-inch nominal diameter core barrel. Photos of the pavement core, logs of the subsurface soils/rock, and results of geotechnical and analytical laboratory testing are presented in the appendices. Bulk soil samples were collected from the pavement borings and combined for classification, strength (R-value), and analytical testing. Preliminary pavement thickness design will be completed by CDOT Staff Materials. The asphalt pavement thicknesses, aggregate base thicknesses (if present), subgrade soil classifications, and subgrade R-values are presented in Table 7.

Table 7. Summary of Existing Pavement and Subgrade Conditions

Boring ID	Existing Asphalt Concrete Thickness (in)	Aggregate Base Thickness (in)	Subgrade Soil Classification (AASHTO)[1]	R-Value[1]
M-21-I-P-1	5.0	Not Encountered	A-6 (9)	11
M-21-I-P-2	6.0	Not Encountered		

1. Subgrade Classification and R-value test results based on combined bulk sample from each pavement boring.

5 ANALYTICAL TEST RESULTS

Analytical testing was completed on representative samples of soils encountered in the borings. The test results can be found in Appendix C and are summarized in Table 8. The Analytical results should be used to select the proper concrete type for the project in accordance with CDOT Standard Specifications (2019). A qualified corrosion engineer should review the laboratory data and boring logs to determine the appropriate level of corrosion protection for materials in contact with these soils.

Table 8. Analytical Test Results

Sample Boring ID	Material	Water Soluble Sulfates, %	Water Soluble Chlorides, %	pH	Resistivity, ohm-cm
M-21-I-P-1/P-2	Lean Clay (Fill)	0.053	0.0029	-	-
M-21-I-B-1	Shale	0.059	0.0010	8.1	784

Sample Boring ID	Material	Water Soluble Sulfates, %	Water Soluble Chlorides, %	pH	Resistivity, ohm-cm
M-21-I-B-2	Lean Clay	0.016	0.0053	8.0	767

6 SEISMIC CONSIDERATIONS

No active faults are known to exist in the immediate vicinity of the proposed bridge location. Based on the site class definitions provided in Table 3.10.3.1-1 of AASHTO LRFD (2020), the site can be categorized as Site Class D. Also based on the recommendations in Table 3.10.6-1 of AASHTO LRFD (2020), the bridge site can be classified as Seismic Zone 1.

The peak ground acceleration (PGA) and the short- and long- period spectral acceleration coefficients (S_s and S_1, respectively) for Site Class B (reference site class) were determined using the seismic design maps from the USGS website. The seismic design parameters for Site Class D are shown in Table 9.

Table 9. Seismic Design Parameters

PGA (0.0 sec)	S_S (0.2 sec)	S_1 (1.0 sec)
0.044 g	0.097 g	0.031 g
A_s (0.0 sec)	S_{DS} (0.2 sec)	S_{D1} (1.0 sec)
0.071 g	0.156 g	0.074 g

7 LIMITATIONS

Our scope of services was performed, and this report was prepared in accordance with generally accepted principles and practices in this area at the time this report was prepared. We make no other warranty, either express or implied.

The classifications, conclusions, and recommendations submitted in this report are based on the data obtained from published and unpublished maps, reports, and geotechnical analyses. Our conclusions and recommendations are based on our understanding of the project as described in this report and the site conditions as interpreted from the explorations. This data may not necessarily reflect variations in the subsurface conditions and water levels occurring at other locations.

The nature and extent of subsurface variations may not become evident until excavation is performed. Variations in the data may also occur with the passage of time. If during construction, fill, soil, rock, or groundwater conditions appear to be different from those described in this report, this office should be advised immediately so we could review these conditions and reconsider our recommendations. If there is a substantial lapse of time between the submission of this report and the start of work at the site, or if conditions have changed because of natural forces or construction operations at or adjacent to the site, we recommend that this report be reviewed to determine the applicability of the conclusions and recommendations concerning the changed conditions or time lapse. We recommend on-site observation of foundation excavations and foundation subgrade conditions by an experienced geotechnical engineer or engineer's representative.

The scope of services of this study did not include hazardous materials sampling or environmental sampling, investigation, or analyses. In addition, we did not evaluate the site for potential impacts to natural resources, including wetlands, endangered species, or environmentally critical areas.

8 REFERENCES

AASHTO LRFD, 9th Edition. AASHTO Load Resistance Factor Design (LRFD) Bridge Design Specifications, Eight Edition. Washington, DC: American Association of State Highway and Transportation Officials. 2020.

Abu-Hejleh, N., O'Neill, M.W., Hanneman, Dennis, Atwooll, W.J., 2003. Improvement of the Geotechnical Axial Design Methodology for Colorado's Drilled Shafts Socketed in Weak Rocks, Final Report: Colorado Department of Transportation Research Branch, July 2003, Report No. CDOT-DTD-R-2003-6.

Colorado Department of Transportation, 2019. CDOT Standard Specifications for Road and Bridge Construction. 2019 Edition.

Respectfully Submitted,
YEH AND ASSOCIATES, INC.

Prepared by:

Cory S. Wallace, EIT, GIT
Staff Engineer

Reviewed by:

COLORADO LICENSED PROFESSIONAL ENGINEER
JG THOMAS MCCALL
56485
2-2-2021

JG T. McCall, PE
Senior Project Engineer

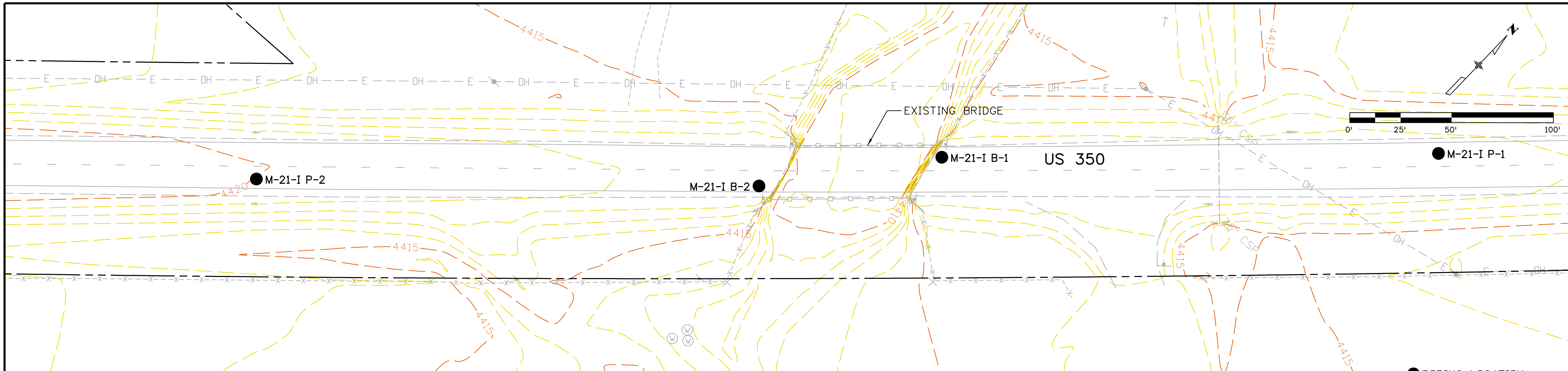
Independent Technical Review by:

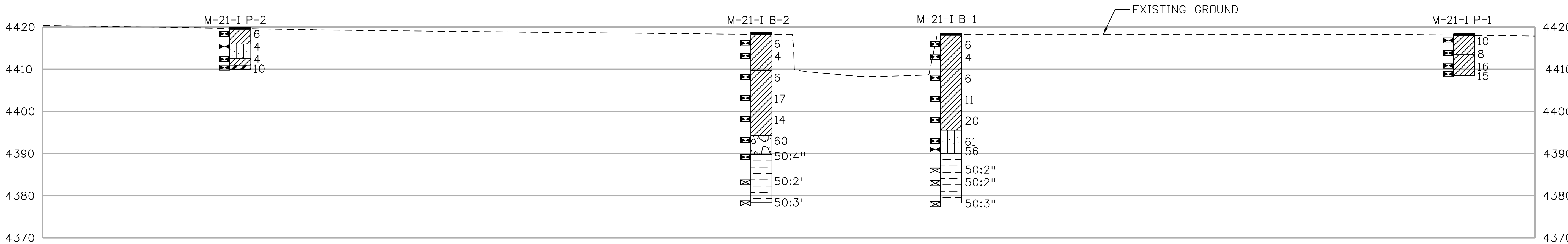
Hsing-Cheng Liu, PE, PhD
Senior Project Manager

Attachments:
Appendix A
Appendix B
Appendix C

APPENDIX A

ENGINEERING GEOLOGY SHEET

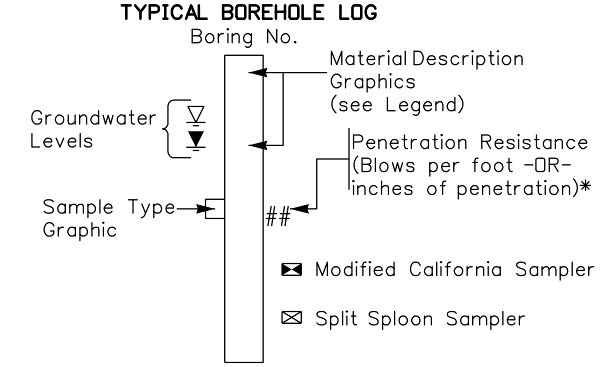




LEGEND

- Asphalt
- USCS Lean/Low Plasticity Clay
- USCS Silty Sand
- Poorly-graded Sandy Gravel
- USCS Fat/High Plasticity Clay
- Shale

TYPICAL BOREHOLE LOG



*e.g. A value of 50/3 or 50:3" indicates that 50 blows were applied to the sampler, with a penetration of 3 inches.

Print Date: 11/13/2020	
File Name: 23558GEOT_Engineering Geology M-21-I.dgn	
Horiz. Scale: 1:50	Vert. Scale: As Noted
Unit Information	Unit Leader Initials

Yeh and Associates, Inc.
Geotechnical · Geological · Construction Services

Sheet Revisions

Date:	Comments	Init.

Colorado Department of Transportation
1480 Quail Lake Loop, Suite A
Colorado Springs, CO 80906
Phone: 719-634-2323
FAX: 719-227-3298
Region 2

As Constructed
No Revisions:
Revised:
Void:

R2 BRIDGE BUNDLE
ENGINEERING GEOLOGY

Designer:	JTM	Structure Numbers	M-21-I
Detailer:	MJW		
Sheet Subset:	Geology	Subset Sheets:	1 of 1

Project No./Code
STM R200-262
23559
Sheet Number

APPENDIX B

KEY TO BORING LOGS

BORING LOGS

PAVEMENT CORE PHOTOS

Yeh and Associates, Inc. Geotechnical • Geological • Construction Services	*Project:*	CDOT Region 2 Bridge Bundle
	Project Number:	220-063

Legend for Symbols Used on Borehole Logs

Sample Types

- Bulk Sample of auger/odex cuttings
- Rock core
- Modified California Sampler (2.5 inch OD, 2.0 inch ID)
- Standard Penetration Test (ASTM D1586)

Drilling Methods

- CORING
- HOLLOW-STEM AUGER
- CORING

Lithology Symbols (see Boring Logs for complete descriptions)

- Asphalt
- Cobbles and gravel
- USCS Fat/High Plasticity Clay
- USCS Lean/Low Plasticity Clay
- Fill
- Fill with Clay as major soil
- Fill with Gravel as major soil
- USCS Clayey Gravel
- USCS Silty, Clayey Gravel
- USCS Poorly-graded Gravel
- USCS Poorly-graded Gravel with Clay
- Low Plasticity Gravelly Clay
- USCS Silt
- USCS Low Plasticity Organic silt or clay
- High Plasticity Sandy Clay
- Poorly-graded Sandy Gravel
- Low Plasticity Sandy Clay
- USCS Clayey Sand
- USCS Silty Sand
- USCS Poorly-graded Sand

- Cobbles and gravel
- Diorite
- Gneiss
- Granite
- Limestone
- Sandstone
- Shale
- Weathered Bedrock

Lab Test Standards

Moisture Content	ASTM D2216
Dry Density	ASTM D7263
Sand/Fines Content	ASTM D421, ASTM C136, ASTM D1140
Atterberg Limits	ASTM D4318
AASHTO Class.	AASHTO M145, ASTM D3282
USCS Class.	ASTM D2487

(Fines = % Passing #200 Sieve
Sand = % Passing #4 Sieve, but not passing #200 Sieve)

Other Lab Test Abbreviations

pH	Soil pH (AASHTO T289-91)
S	Water-Soluble Sulfate Content (AASHTO T290-91, ASTM D4327)
Chl	Water-Soluble Chloride Content (AASHTO T291-91, ASTM D4327)
S/C	Swell/Collapse (ASTM D4546)
UCCS	Unconfined Compressive Strength (Soil - ASTM D2166, Rock - ASTM D7012)
R-Value	Resistance R-Value (ASTM D2844)
DS (C)	Direct Shear cohesion (ASTM D3080)
DS (phi)	Direct Shear friction angle (ASTM D3080)
Re	Electrical Resistivity (AASHTO T288-91)
PtL	Point Load Strength Index (ASTM D5731)

Notes

1. Visual classifications are in general accordance with ASTM D2488, "Standard Practice for Description and Identification of Soils (Visual-Manual Procedures)".
2. "Penetration Resistance" on the Boring Logs refers to the uncorrected N value for SPT samples only, as per ASTM D1586. For samples obtained with a Modified California (MC) sampler, drive depth is 12 inches, and "Penetration Resistance" refers to the sum of all blows. Where blow counts were > 50 for the 3rd increment (SPT) or 2nd increment (MC), "Penetration Resistance" combines the last and 2nd-to-last blows and lengths; for other increments with > 50 blows, the blows for the last increment are reported.
3. The Modified California sampler used to obtain samples is a 2.5-inch OD, 2.0-inch ID (1.95-inch ID with liners), split-barrel sampler with internal liners, as per ASTM D3550. Sampler is driven with a 140-pound hammer, dropped 30 inches per blow.
4. "ER" for the hammer is the Reported Calibrated Energy Transfer Ratio for that specific hammer, as provided by the drilling company.

Boring Began: 9/1/2020
Boring Completed: 9/1/2020
Drilling Method(s): Coring / Solid-Stem Auger
Driller: Vine Laboratories
Drill Rig: CME 750X Buggy
Hammer: Automatic (hydraulic), ER: %

Total Depth: 10.0 ft
Ground Elevation: 4418.43
Coordinates: N: 426240.4 E: 500977.8
Location:
Logged By: C. Wallace
Final By: J. McCall

Weather Notes: Clear, 70s
Inclination from Horiz.: Vertical
Night Work: ☐

Groundwater Levels: Not Observed			
Symbol			
Depth	-	-	-
Date	-	-	-

Elevation (feet)	Depth (feet)	Blows per 6 in	Penetration Resistance	Material Description	Moisture Content (%)	Dry Density (pcf)	Gravel Content (%)	Sand Content (%)	Fines Content (%)	Liquid Limit	Plasticity Index	AASHTO & USCS Classifications	Field Notes and Other Lab Tests
				0.0 - 0.4 ft. ASPHALT (5 inches).									
				0.4 - 5.0 ft. Lean CLAY (CL) (Fill), brown, dry to moist, medium stiff to stiff.									
		5-5	10										
4415		4-4	8		11.6	116.8	0.0	13.0	87.0	33	20	A-6 (16) CL	S/C=3.5%
	5			**5.0 - 10.0 ft. Lean-to-fat CLAY**, dark brown, moist, stiff.									
		5-11	16		11.6	116.8	0.0	5.0	95.0	45	28	A-7-6 (28) CL	
4410		5-10	15										
	10			Bottom of Hole at 10.0 ft.									

4405

4400

4395

Boring Began: 9/1/2020
Boring Completed: 9/1/2020
Drilling Method(s): Coring / Solid-Stem Auger
Driller: Vine Laboratories
Drill Rig: CME 750X Buggy
Hammer: Automatic (hydraulic), ER: %

Total Depth: 10.0 ft
Ground Elevation: 4419.97
Coordinates: N: 425828.8 E: 500568.5
Location:
Logged By: C. Wallace
Final By: J. McCall

Weather Notes: Cloudy, 50s
Inclination from Horiz.: Vertical
Night Work: ☐

Groundwater Levels: Not Observed			
Symbol			
Depth	-	-	-
Date	-	-	-

Elevation (feet)	Depth (feet)	Blows per 6 in	Penetration Resistance	Material Description	Moisture Content (%)	Dry Density (pcf)	Gravel Content (%)	Sand Content (%)	Fines Content (%)	Liquid Limit	Plasticity Index	AASHTO & USCS Classifications	Field Notes and Other Lab Tests
				0.0 - 0.5 ft. ASPHALT (6 inches).									
		3-3	6	**0.5 - 4.0 ft. Lean CLAY (CL) (Fill)**, brown, moist, medium stiff.	17.8	106.9	1.0	11.0	88.0	36	21	A-6 (18) CL	S/C=0.9%
4415	5	2-2	4	**4.0 - 7.5 ft. Silty SAND (SM)**, brown, moist, very loose, very fine to fine sand.									
		2-2	4	**7.5 - 9.0 ft. Lean CLAY with sand (CL)**, brown, moist, medium stiff, calcite.									
4410	10	4-6	10	**9.0 - 10.0 ft. Fat CLAY with sand (CH)**, brown, moist, stiff.									

Bottom of Hole at 10.0 ft.

4405

4400

Boring Began: 9/1/2020
Boring Completed: 9/1/2020
Drilling Method(s): Hollow-Stem Auger
Driller: Vine Laboratories
Drill Rig: CME 750X Buggy
Hammer: Automatic (hydraulic), ER: %

Total Depth: 40.3 ft
Ground Elevation: 4418.55
Coordinates: N: 426069.9 E: 500803.5
Location:

Logged By: C. Wallace
Final By: J. McCall

Weather Notes: Clear, 60s
Inclination from Horiz.: Vertical

Night Work: ☐

Groundwater Levels: Not Observed			
Symbol			
Depth	-	-	-
Date	-	-	-

Elevation (feet)	Depth (feet)	Sample Type/Depth	Drilling Method	Soil Samples: Blows per 6 in	Soil Samples: Penetration Resistance	Lithology	Material Description	Moisture Content (%)	Dry Density (pcf)	Gravel Content (%)	Sand Content (%)	Fines Content (%)	Atterberg Limits: Liquid Limit	Atterberg Limits: Plasticity Index	AASHTO & USCS Classifications	Field Notes and Other Lab Tests
	0						**0.0 - 0.5 ft. ASPHALT** (6 inches).									
							0.5 - 13.0 ft. Lean CLAY with sand (CL) (Fill), brown, moist, medium stiff.									
				3-3	6											
4415																
	5			2-2	4			18.4	99.2	1.0	12.0	87.0	28	12	A-6 (9) CL	
4410																
	10			3-3	6											
4405							**13.0 - 23.0 ft. Lean CLAY (CL)**, dark brown mottled with yellowish brown, moist, stiff to very stiff, calcite.									
	15			4-7	11											
4400																
	20			8-12	20											
4395							**23.0 - 28.5 ft. Silty SAND with gravel (SM)**, black mottled with yellowish brown, moist, dense to very dense.									

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Project Name: CDOT Region 2 Bridge Bundle

Project Number: 220-063 Boring No.: **M-21-I-B-1**

Elevation (feet)	Depth (feet)	Sample Type/Depth	Drilling Method	Soil Samples: Blows per 6 in	Soil Samples: Penetration Resistance	Lithology	Material Description	Moisture Content (%)	Dry Density (pcf)	Gravel Content (%)	Sand Content (%)	Fines Content (%)	Atterberg Limits: Liquid Limit	Atterberg Limits: Plasticity Index	AASHTO & USCS Classifi-cations	Field Notes and Other Lab Tests
				25-36	61		**23.0 - 28.5 ft. Silty SAND with gravel (SM)**, black mottled with yellowish brown, moist, dense to very dense.	3.7		24.0	62.0	14.0				
				24-32	56											
4390	30						**28.5 - 40.3 ft. SHALE**, gray - brown, moderately weathered, very hard, fissile, moist.									
				50:2"	50:2"			4.0		0.0	5.0	95.0	43	29	A-7-6 (28) CL	pH=8.1 S=0.059% Chl=0.0010% Re=784ohm·cm
4385	35			50:2"	50:2"											
4380	40			50:3"	50:3"											

Bottom of Hole at 40.3 ft.

4375

4370

4365

Yeh and Associates, Inc.
Geotechnical • Geological • Construction Services

Project Name: CDOT Region 2 Bridge Bundle

Project Number: 220-063 *Boring No.:* **M-21-I-B-2**

Boring Began: 9/1/2020
Boring Completed: 9/1/2020
Drilling Method(s): Hollow-Stem Auger
Driller: Vine Laboratories
Drill Rig: CME 750X Buggy
Hammer: Automatic (hydraulic), ER: %

Total Depth: 40.3 ft
Ground Elevation: 4418.76
Coordinates: N: 425997.5 E: 500748.7
Location:

Logged By: C. Wallace
Final By: J. McCall

Weather Notes: Cloudy, 60s
Inclination from Horiz.: Vertical

Night Work: ☐

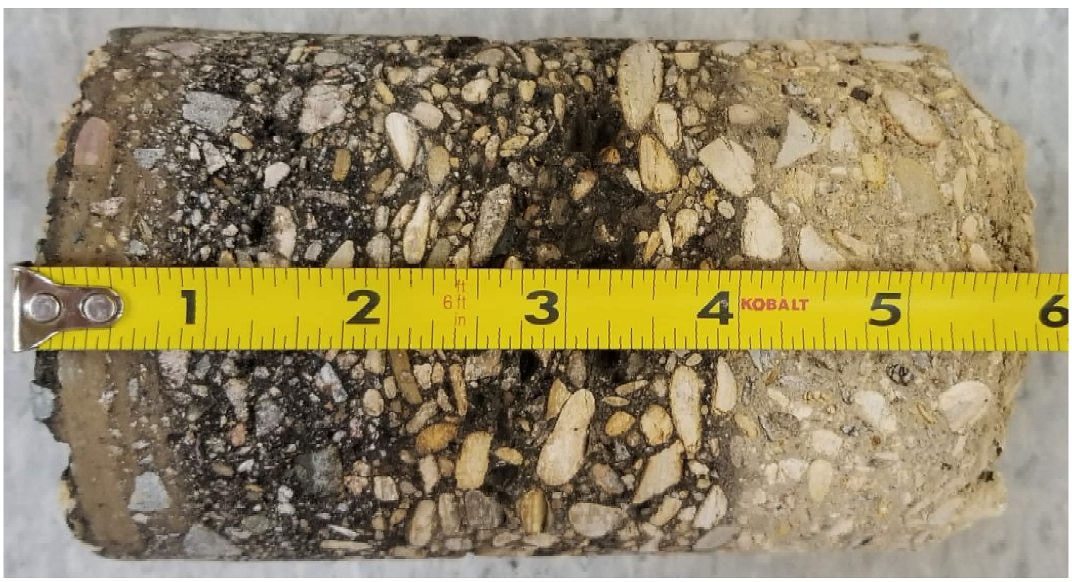
Groundwater Levels: Not Observed			
Symbol			
Depth	-	-	-
Date	-	-	-

Elevation (feet)	Depth (feet)	Sample Type/Depth	Drilling Method	Soil Samples: Blows per 6 in	Soil Samples: Penetration Resistance	Lithology	Material Description	Moisture Content (%)	Dry Density (pcf)	Gravel Content (%)	Sand Content (%)	Fines Content (%)	Atterberg Limits: Liquid Limit	Atterberg Limits: Plasticity Index	AASHTO & USCS Classifications	Field Notes and Other Lab Tests
	0						**0.0 - 0.5 ft. ASPHALT** (6 inches).									
							0.5 - 9.0 ft. Lean CLAY (CL) (Fill), brown, moist, medium stiff.									
				2-4	6											
4415																
	5			2-2	4											
4410							**9.0 - 24.5 ft. Lean CLAY (CL)**, brown, moist, medium stiff.									
	10			2-4	6			19.7	107.5	0.0	10.0	90.0	39	25	A-6 (22) CL	S/C=0.3%
4405							Dark brown to brown, stiff to very stiff.									
	15			7-10	17			19.7		0.0	3.0	97.0	37	22	A-6 (21) CL	pH=8 S=0.016% Chl=0.0053% Re=767ohm·cm
4400																
	20			5-9	14											
4395																

Elevation (feet)	Depth (feet)	Sample Type/Depth	Drilling Method	Soil Samples: Blows per 6 in	Soil Samples: Penetration Resistance	Lithology	Material Description	Moisture Content (%)	Dry Density (pcf)	Gravel Content (%)	Sand Content (%)	Fines Content (%)	Atterberg Limits: Liquid Limit	Atterberg Limits: Plasticity Index	AASHTO & USCS Classifications	Field Notes and Other Lab Tests
				20-40	60		**24.5 - 29.0 ft. Poorly graded GRAVEL with sand (GP)**, brown and yellow, moist, dense, sandstone and limestone gravels.									
4390				50:4"	50:4"		**29.0 - 40.3 ft. SHALE**, gray, moderately weathered, very hard, fissile.	11.0	125.7	1.0	5.0	94.0	50	34	A-7-6 (34) CH	UCCS=249.4 psi
	30															
4385																
	35			50:2"	50:2"											
4380																
	40			50:3"	50:3"											
4375																
4370																
4365																

Bottom of Hole at 40.3 ft.

Boring:	**P-1**	AC:	**5"**
Roadway:	**US 350**	PCC:	**-**
Direction:	**Southbound**	Base:	**-**
Lane:	**Outside**	Notes:	**-**



Boring:	**P-2**	AC:	**6"**
Roadway:	**US 350**	PCC:	**-**
Direction:	**Northbund**	Base:	**-**
Lane:	**Outside**	Notes:	**-**

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Pavement Core Photographs

FIGURE **B-1**

PROJECT NO.	220-063	DATE:	11/6/2020
FIGURE BY:	BHL	YEH OFFICE:	Colorado Springs
CHECKED BY:	JTM		

CDOT Region 2 Bridge Bundle
Structure M-21-I

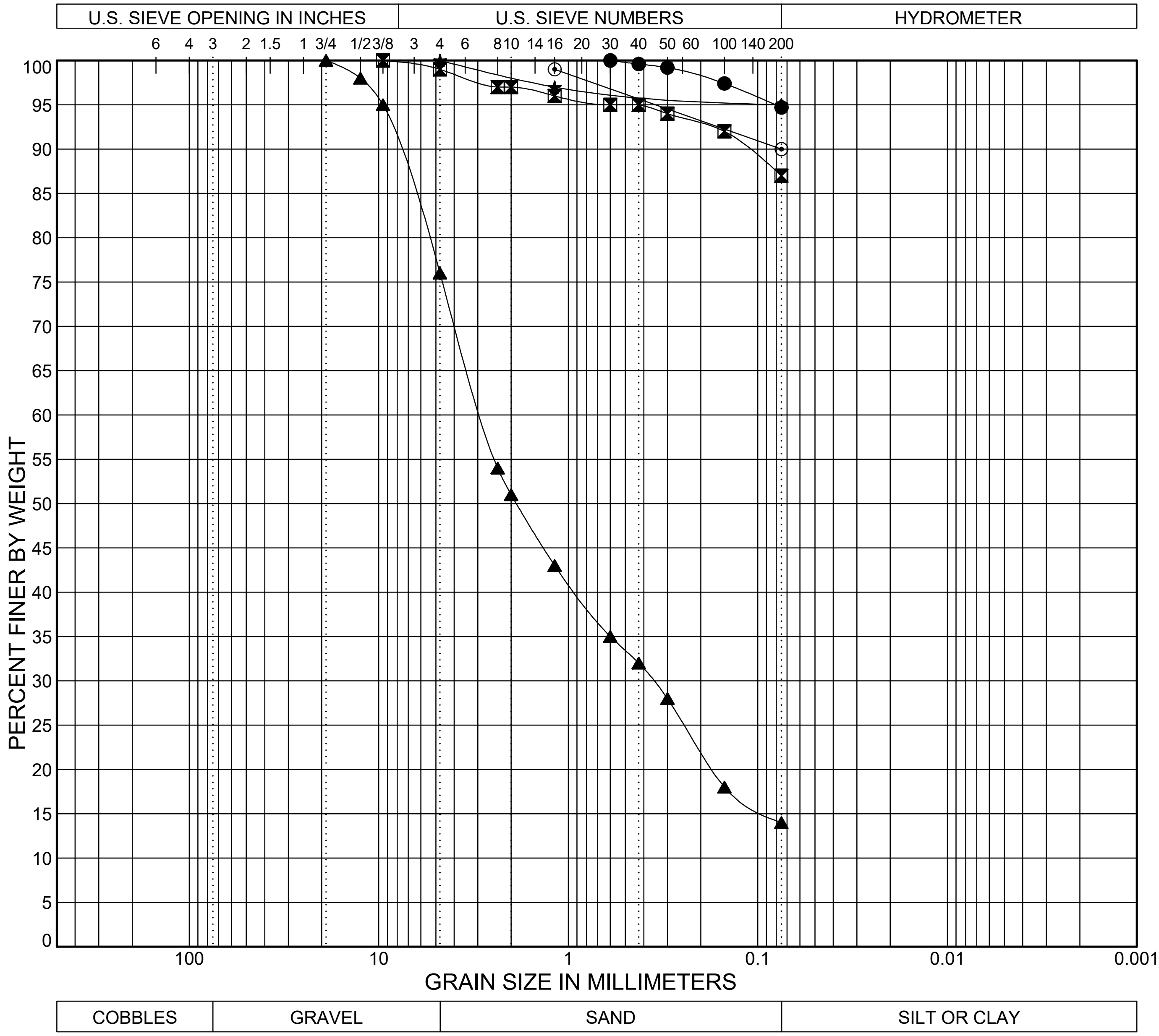
APPENDIX C

SUMMARY OF LABORATORY TEST RESULTS

Summary of Laboratory Test Results

Project No: 220-063 Project Name: CDOT Region 2 Bridge Bundle Date: 11-13-2020

Sample Location			Natural Moisture Content (%)	Natural Dry Density (pcf)	Gradation			Atterberg			pH	Water Soluble Sulfate (%)	Water Soluble Chloride (%)	Resistivity (ohm-cm)	Swell (+) / Collapse (-) (% at Load in psf)	Unconf. Comp. Strength (psi)	R-Value	Classification	
Boring No.	Depth (ft)	Sample Type			Gravel > #4 (%)	Sand (%)	Fines < #200 (%)	LL	PL	PI								AASHTO	USCS
M-21-I Scour	0	BULK	4.5		0.0	5.3	94.7												
M-21-I-B-1	5.0	MC	18.4	99.2	1.0	12.0	87.0	28	16	12								A-6 (9)	CL
M-21-I-B-1	25.0	MC	3.7		24.0	62.0	14.0												
M-21-I-B-1	32.0	SPT	4		0.0	5.0	95.0	43	14	29	8.1	0.059	0.0010	784				A-7-6 (28)	CL
M-21-I-B-2	10.0	MC	19.7	107.5		10.0	90.0	39	14	25					0.3 @ 1000			A-6 (22)	CL
M-21-I-B-2	15.0	MC	19.7			3.0	97.0	37	15	22	8	0.016	0.0053	767				A-6 (21)	CL
M-21-I-B-2	29.0	MC	11	125.7	1.0	5.0	94.0	50	16	34						249.4		A-7-6 (34)	CH
M-21-I-P-1	4.0	MC	11.6	116.8		13.0	87.0	33	13	20					3.5 @ 200			A-6 (16)	CL
M-21-I-P-1	7.0	MC	11.6	116.8	0.0	5.0	95.0	45	17	28								A-7-6 (28)	CL
M-21-I-P-1/P-2	2.5	BULK	11.3		13.0	27.0	60.0	34	14	20		0.053	0.0029				11	A-6 (9)	CL
M-21-I-P-2	1.0	MC	17.8	106.9	1.0	11.0	88.0	36	15	21					0.9 @ 200			A-6 (18)	CL



	BOREHOLE	DEPTH (ft)	AASHTO Classification	USCS Classification	LL	PL	PI	%Gravel	%Sand	%Fines: %Silt	%Fines: %Clay
●	**M-21-I Scour**	**0.0**						**0.0**	**5.3**	**94.7**	
⊠	**M-21-I-B-1**	**5.0**	**A-6 (9)**	**CL**	**28**	**16**	**12**	**1.0**	**12.0**	**87.0**	
▲	**M-21-I-B-1**	**25.0**						**24.0**	**62.0**	**14.0**	
★	**M-21-I-B-1**	**32.0**	**A-7-6 (28)**	**CL**	**43**	**14**	**29**	**0.0**	**5.0**	**95.0**	
⊙	**M-21-I-B-2**	**10.0**	**A-6 (22)**	**CL**	**39**	**14**	**25**		**9.0**	**90.0**	

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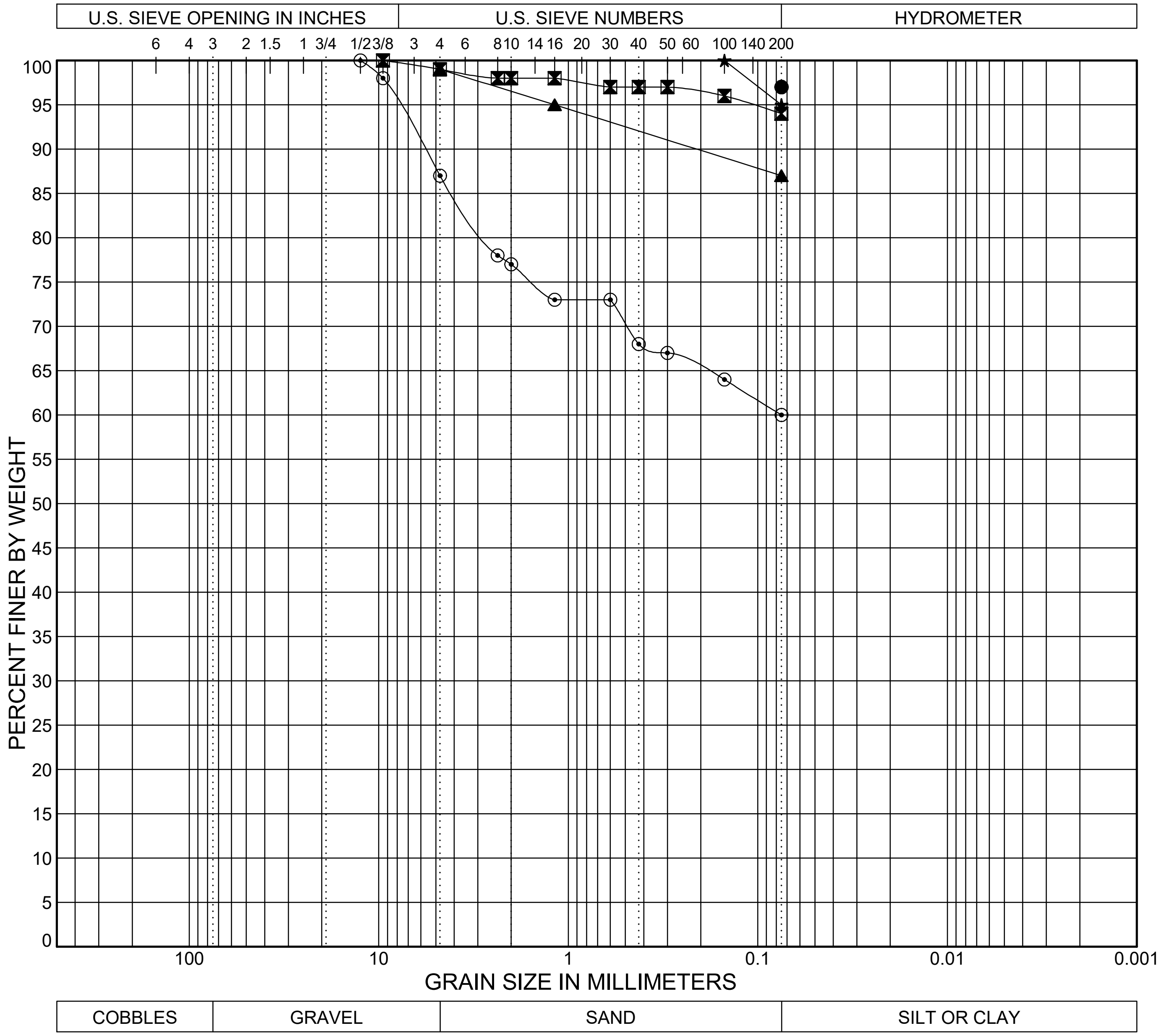
SIEVE ANALYSIS

FIGURE C- 2

Project No.	220-063	Date:	11-13-2020
Report By:	D. Gruenwald	Yeh Lab:	Colorado Springs
Checked By:	J. McCall		

CDOT Region 2 Bridge Bundle
Structure M-21-I



	BOREHOLE	DEPTH (ft)	AASHTO Classification	USCS Classification	LL	PL	PI	%Gravel	%Sand	%Fines %Silt	%Fines %Clay
●	**M-21-I-B-2**	**15.0**	**A-6 (21)**	**CL**	**37**	**15**	**22**			**97.0**	
⧗	**M-21-I-B-2**	**29.0**	**A-7-6 (34)**	**CH**	**50**	**16**	**34**	**1.0**	**5.0**	**94.0**	
▲	**M-21-I-P-1**	**4.0**	**A-6 (16)**	**CL**	**33**	**13**	**20**		**12.0**	**87.0**	
★	**M-21-I-P-1**	**7.0**	**A-7-6 (28)**	**CL**	**45**	**17**	**28**	**0.0**	**5.0**	**95.0**	
⊙	**M-21-I-P-1/P-2**	**2.5**	**A-6 (9)**	**CL**	**34**	**14**	**20**	**13.0**	**27.0**	**60.0**	

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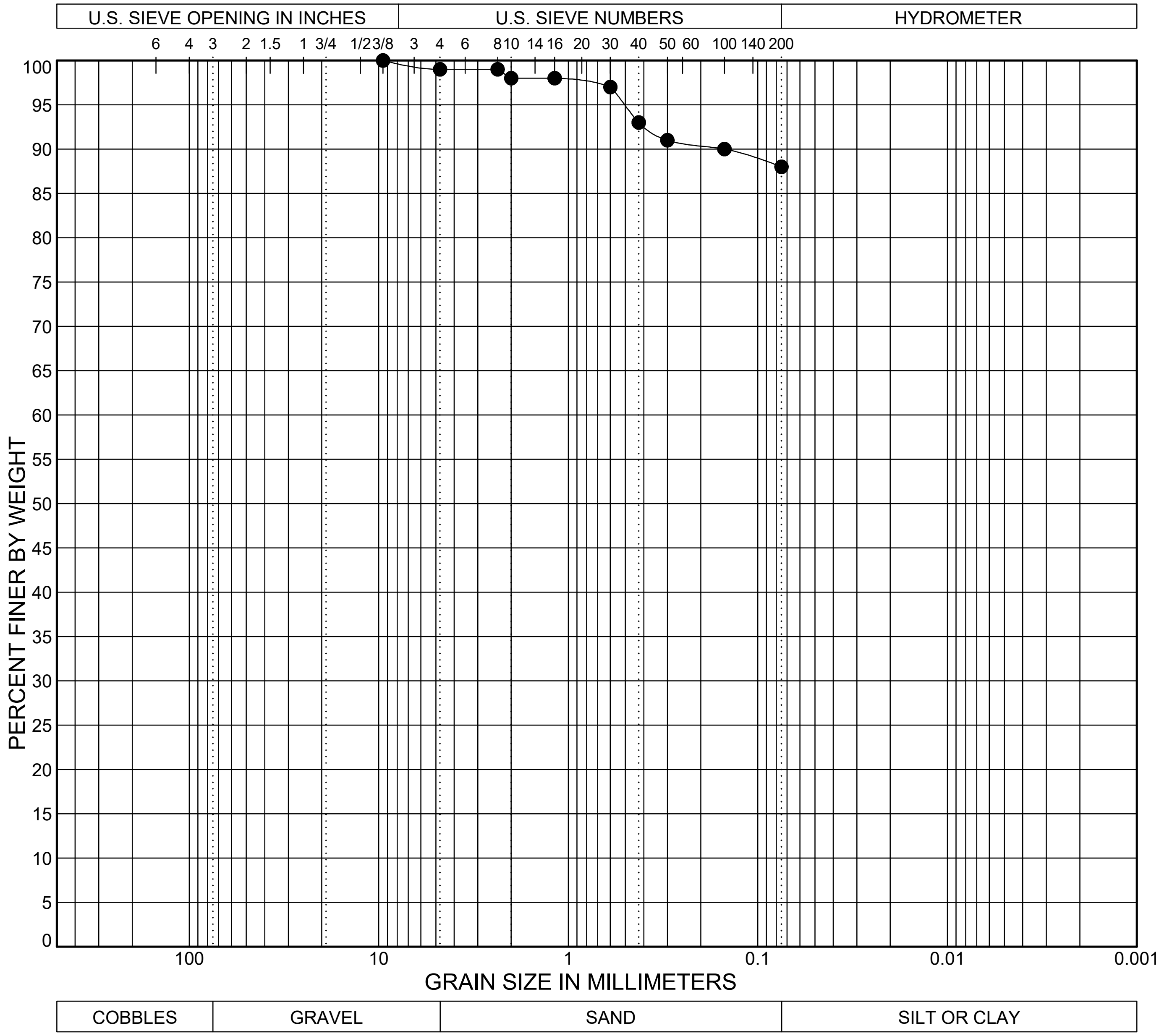
SIEVE ANALYSIS

FIGURE C- 3

Project No. 220-063 Date: 11-13-2020
Report By: D. Gruenwald Yeh Lab: Colorado Springs
Checked By: J. McCall

CDOT Region 2 Bridge Bundle
Structure M-21-I



BOREHOLE	DEPTH (ft)	AASHTO Classification	USCS Classification	LL	PL	PI	%Gravel	%Sand	%Fines: %Silt	%Fines: %Clay
● **M-21-I-P-2**	**1.0**	**A-6 (18)**	**CL**	**36**	**15**	**21**	**1.0**	**11.0**	**88.0**	

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SIEVE ANALYSIS

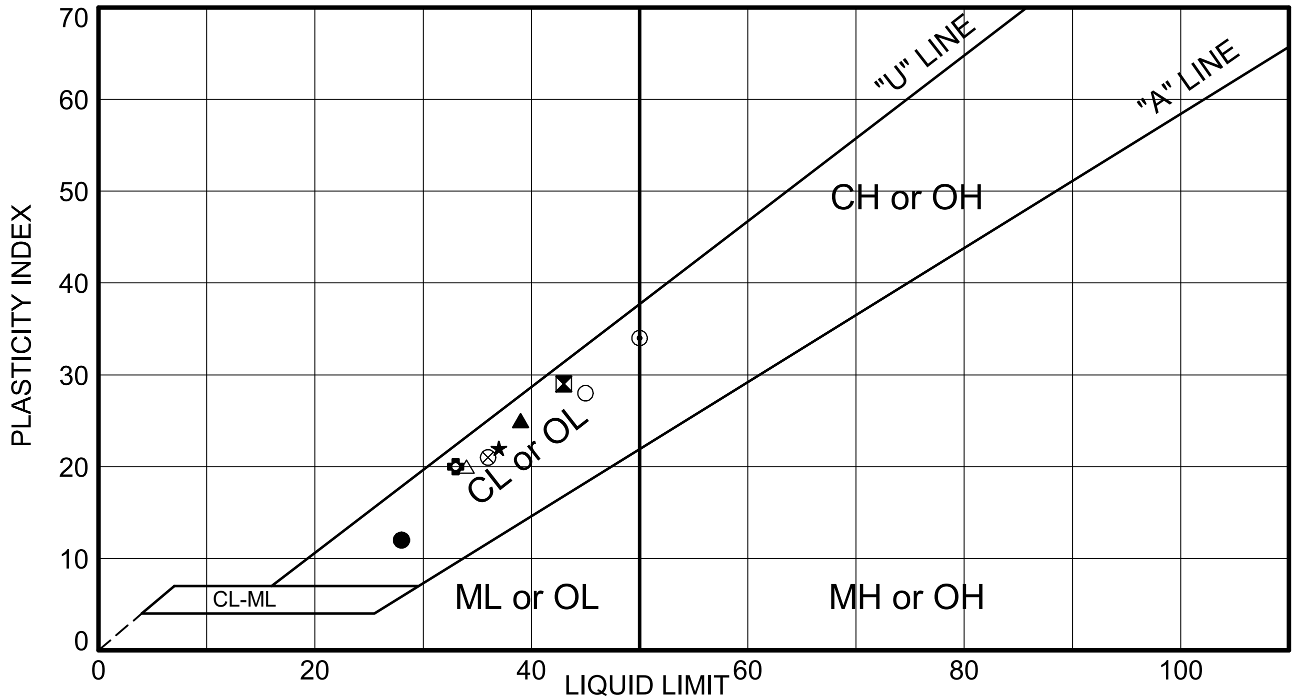
CDOT Region 2 Bridge Bundle
Structure M-21-I

FIGURE

C- 4

Project No.	220-063	Date:	11-13-2020
Report By:	D. Gruenwald	Yeh Lab:	Colorado Springs
Checked By:	J. McCall		

03 GRAIN SIZE YEH 220-063 R2 BRIDGE BUNDLE.GPJ 2019 YEH COLORADO TEMPLATE.GDT 2019 YEH COLORADO LIBRARY.GLB 11/13/20



	BOREHOLE	DEPTH (ft)	LL	PL	PI	Passing #200	USCS Sample Description and Symbol	AASHTO Class.
●	**M-21-I-B-1**	**5.0**	**28**	**16**	**12**	**87.0**	**LEAN CLAY (CL)**	**A-6 (9)**
⧗	**M-21-I-B-1**	**32.0**	**43**	**14**	**29**	**95.0**	**LEAN CLAY (CL)**	**A-7-6 (28)**
▲	**M-21-I-B-2**	**10.0**	**39**	**14**	**25**	**90.0**	**LEAN CLAY (CL)**	**A-6 (22)**
★	**M-21-I-B-2**	**15.0**	**37**	**15**	**22**	**97.0**	**LEAN CLAY (CL)**	**A-6 (21)**
⊙	**M-21-I-B-2**	**29.0**	**50**	**16**	**34**	**94.0**	**FAT CLAY (CH)**	**A-7-6 (34)**
✿	**M-21-I-P-1**	**4.0**	**33**	**13**	**20**	**87.0**	**LEAN CLAY (CL)**	**A-6 (16)**
○	**M-21-I-P-1**	**7.0**	**45**	**17**	**28**	**95.0**	**LEAN CLAY (CL)**	**A-7-6 (28)**
△	**M-21-I-P-1/P-2**	**2.5**	**34**	**14**	**20**	**60.0**	**SANDY LEAN CLAY (CL)**	**A-6 (9)**
⊗	**M-21-I-P-2**	**1.0**	**36**	**15**	**21**	**88.0**	**LEAN CLAY (CL)**	**A-6 (18)**

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ATTERBERG LIMITS

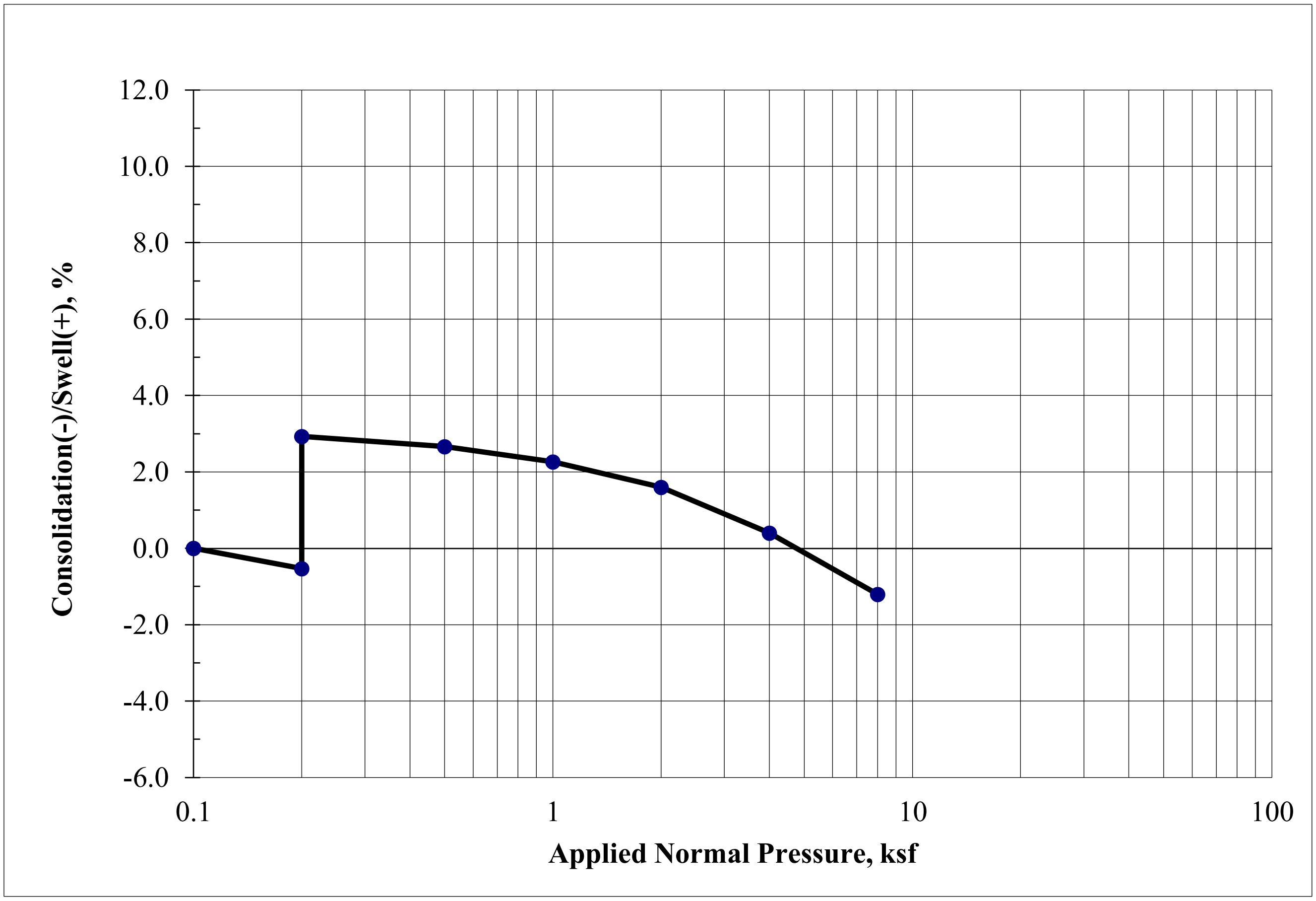
CDOT Region 2 Bridge Bundle
Structure M-21-I

FIGURE

C - 5

Project No.	220-063	Date:	11-13-2020
Report By:	D. Gruenwald	Yeh Lab:	Colorado Springs
Checked By:	J. McCall		

SWELL/CONSOLIDATION TEST - ASTM D 4546

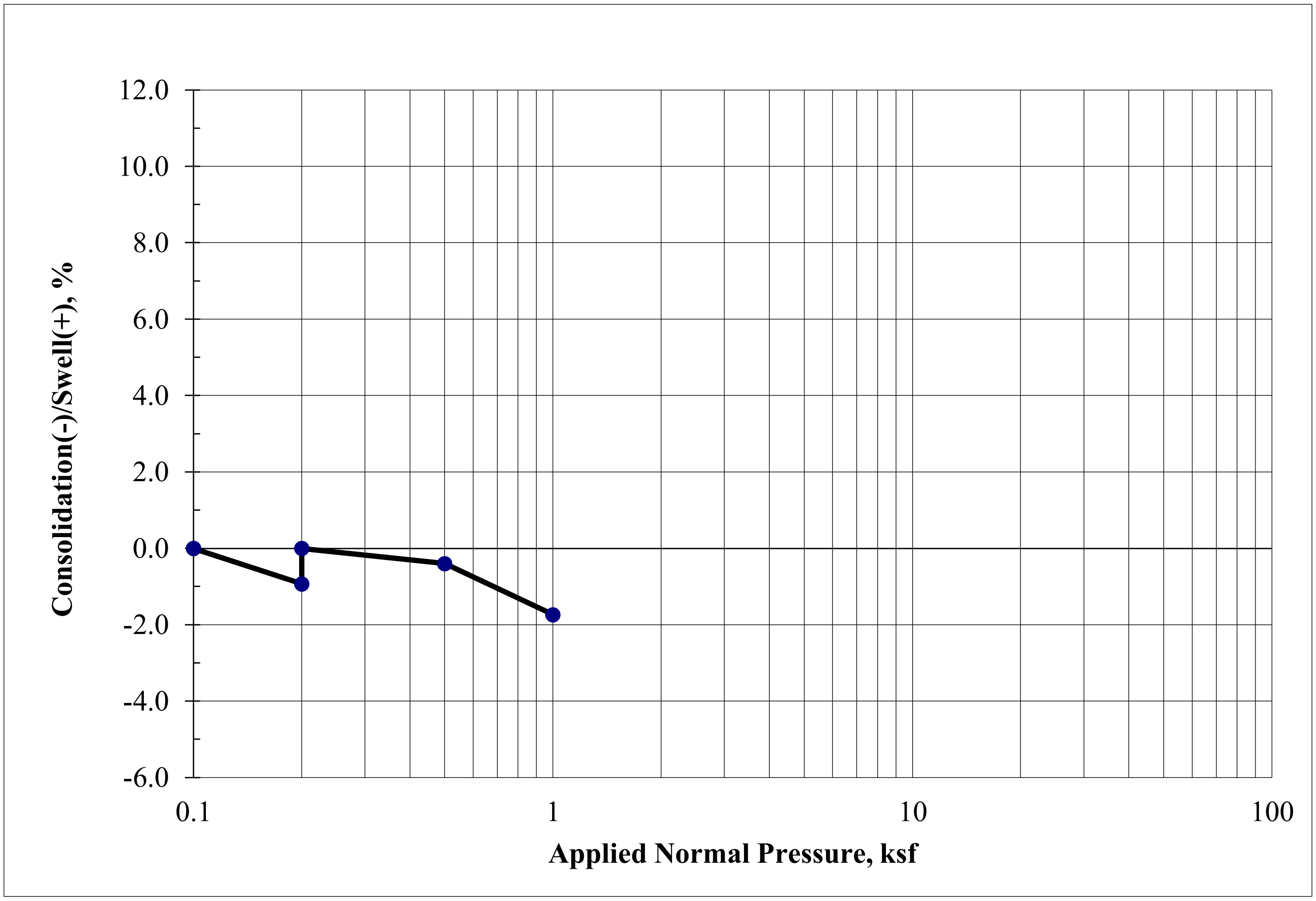


Boring ID	P-1
Sample Depth (ft)	4.0
Date Sampled	9/1/2020

Swell/ Consolidation (%)	3.5
Natural Moisture Content (%)	11.6
Saturated Moisture Content (%)	16
Dry Density (pcf)	116.8

Yeh and Associates, Inc. Geotechnical • Geological • Construction Services				**SWELL/ CONSOLIDATION TEST RESULTS**	**FIGURE**
Project No.	220-063	Date:	11/6/2020	CDOT Region 2 Bridge Bundle	**C-5**
Report By:	DG	Yeh Lab:	Colorado Springs	Structure M-21-I	
Checked By:	JTM				

SWELL/CONSOLIDATION TEST - ASTM D 4546

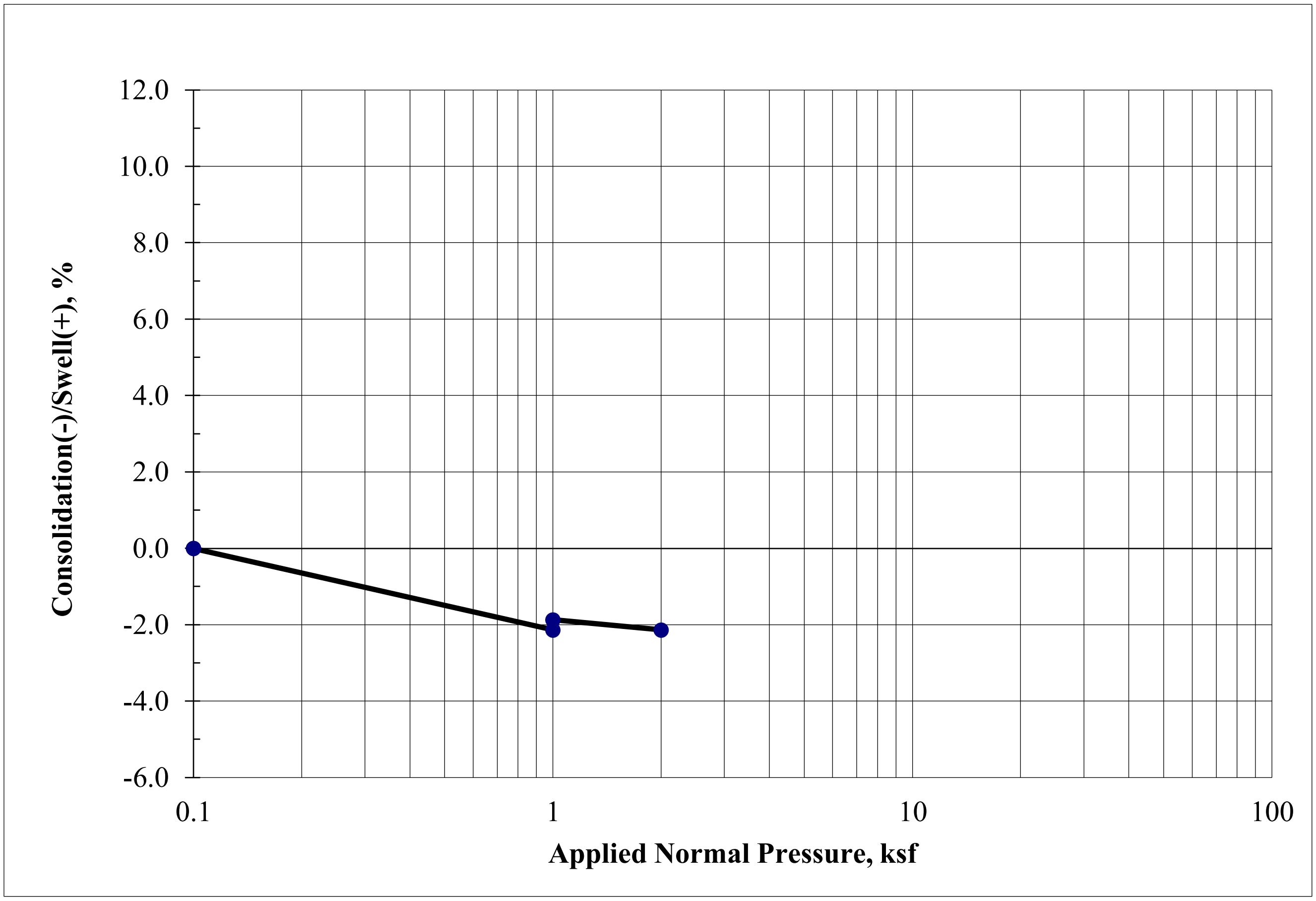


Boring ID	P-2
Sample Depth (ft)	1.0
Date Sampled	9/1/2020

Swell/ Consolidation (%)	0.9
Natural Moisture Content (%)	17.8
Saturated Moisture Content (%)	21.2
Dry Density (pcf)	106.9

Yeh and Associates, Inc. Geotechnical • Geological • Construction Services				**SWELL/ CONSOLIDATION TEST RESULTS**	**FIGURE**
Project No.	220-063	Date:	11/6/2020	CDOT Region 2 Bridge Bundle	**C-6**
Report By:	DG	Yeh Lab:	Colorado Springs	Structure M-21-I	
Checked By:	JTM				

SWELL/CONSOLIDATION TEST - ASTM D 4546



Boring ID	B-2
Sample Depth (ft)	10.0
Date Sampled	9/1/2020

Swell/ Consolidation (%)	0.3
Natural Moisture Content (%)	19.7
Saturated Moisture Content (%)	19.8
Dry Density (pcf)	107.5

Yeh and Associates, Inc.
Geotechnical • Geological • Construction Services

SWELL/ CONSOLIDATION TEST RESULTS

FIGURE C-7

Project No.	220-063	Date:	11/6/2020
Report By:	DG	Yeh Lab:	Colorado Springs
Checked By:	JTM		

CDOT Region 2 Bridge Bundle
Structure M-21-I

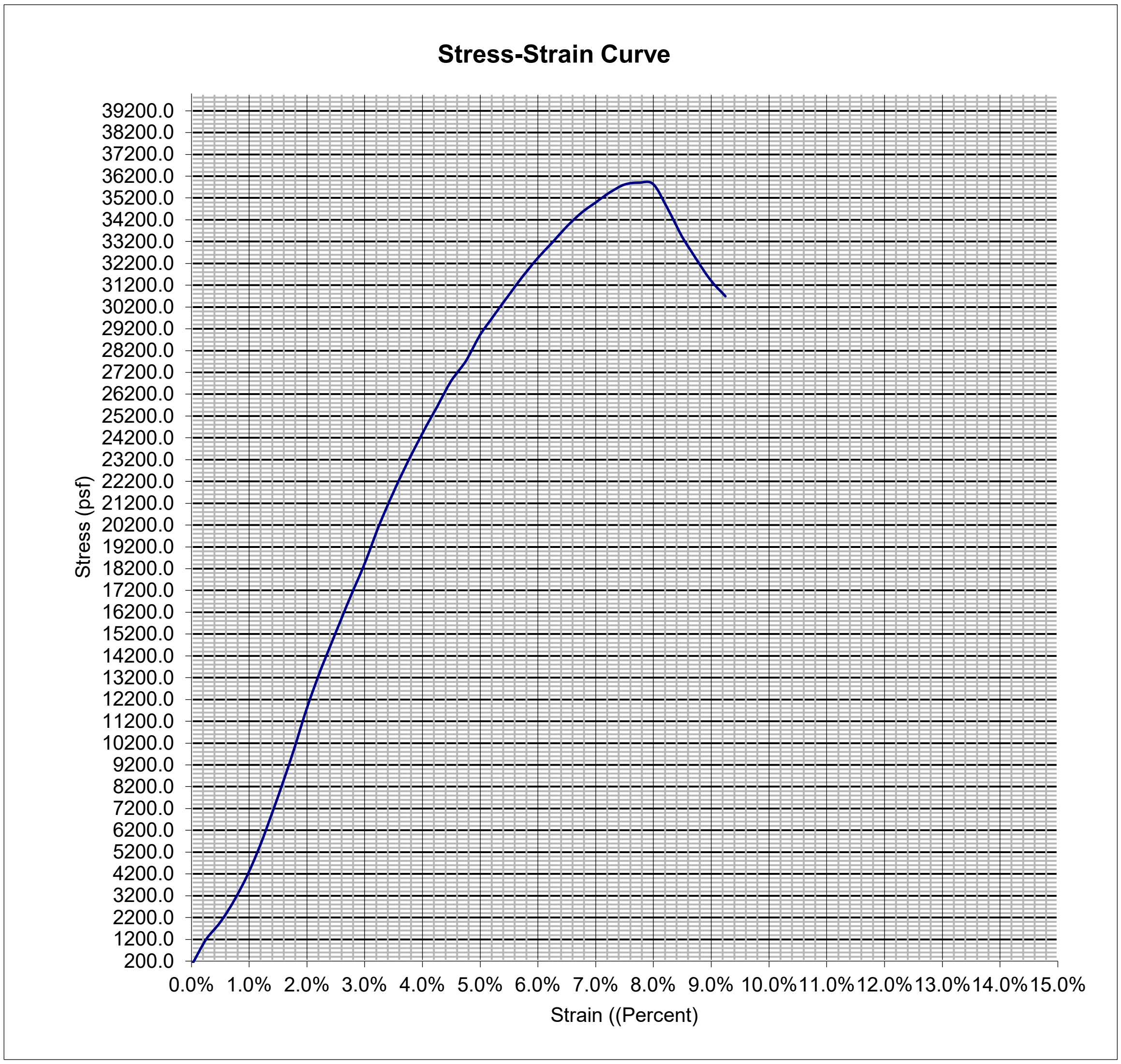
Yeh and Associates, Inc.
Consulting Engineers & Scientists

Clay- Lab Denver

STRESS-STRAIN CURVE
OF COHESIVE SOIL (ASTM D 2166)

Project No: 220-063 Project Name: CDOT Region 2 Bridge Bundle M-21-I
Sampled b JTM Date Sampled: 9/23/2020 Date Tested: 10/7/20
Boring No: B-2 Depth (ft): 29 Blow Counts:
Tested by: M.A Checked by: JTM
Soil Classification: A-7-6 (34) / CH

Axial Strain (%)	Axial Stress (psf)
0.0%	0.0
0.2%	1175.1
0.5%	1986.3
0.7%	3038.0
1.0%	4313.7
1.2%	5923.6
1.5%	7768.1
1.7%	9695.2
2.0%	11810.4
2.2%	13625.7
2.5%	15277.7
2.7%	16897.0
3.0%	18426.6
3.2%	20186.5
3.5%	21727.8
3.7%	23109.1
4.0%	24402.4
4.2%	25617.9
4.5%	26817.3
4.7%	27718.9
5.0%	28915.2
5.2%	29857.2
5.5%	30766.0
5.7%	31641.6
6.0%	32452.0
6.2%	33160.5
6.5%	33892.4
6.7%	34514.3
7.0%	35004.0
7.2%	35463.1
7.5%	35823.5
7.7%	35908.6
8.0%	35829.4
8.2%	34701.0
8.5%	33424.8
8.7%	32371.0
9.0%	31398.7
9.2%	30699.6



Unconfined Compressive Strength (q_u) = 35909 psf @ 7.7% Strain
%

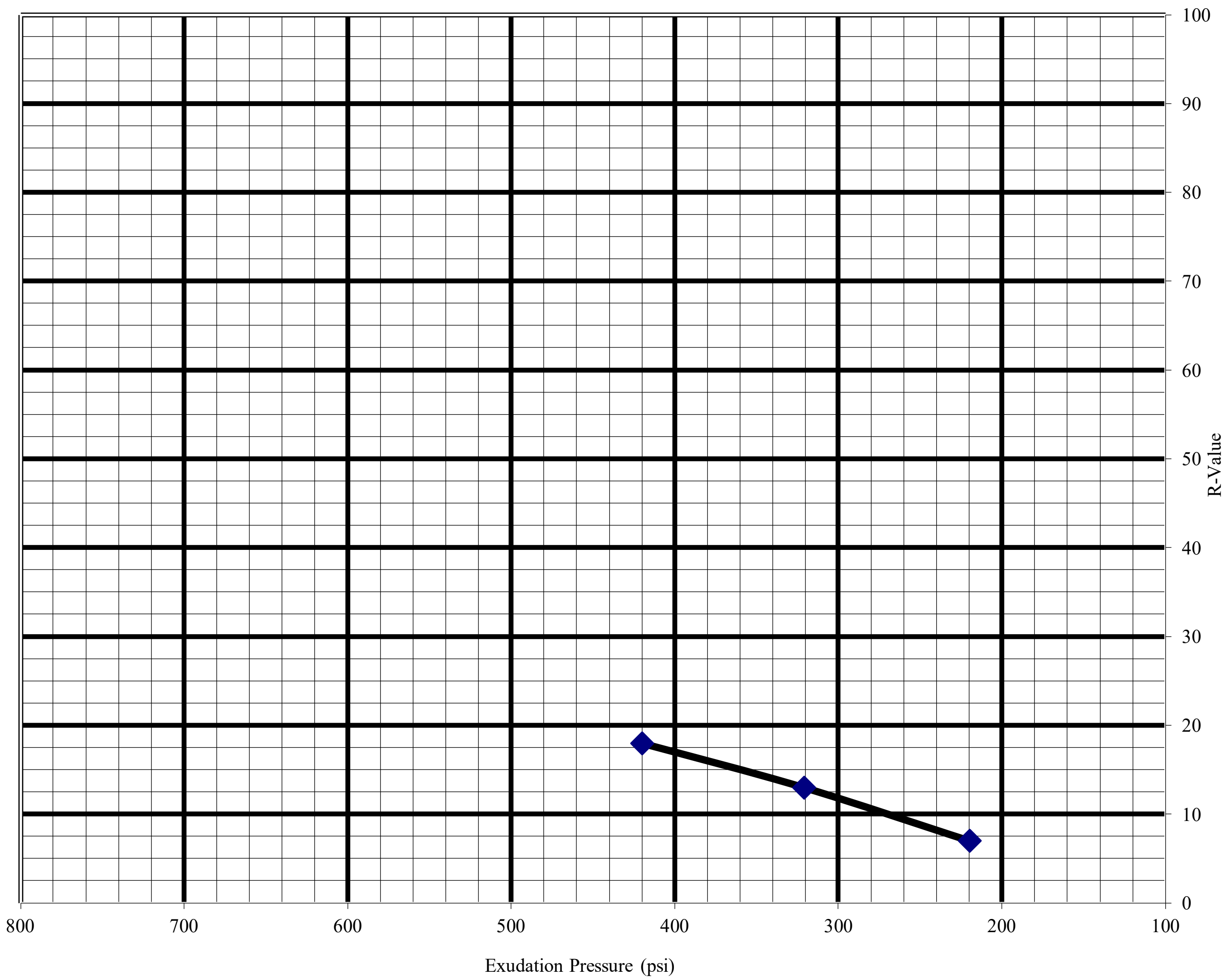
Natural Moisture: 11.0 %
Natural Density(Dry): 125.7 pcf
Average Diameter (D): 1.929 inches
Average High (L): 4.001 inches
L/D Ritio: 2.07

YEH AND ASSOCIATES, INC

R-Value Test Report

Project Number:	220-063	**Project Name:**	CDOT Region 2 Bridge Bundle
Sample Id:	P-1 / P-2	**Depth (ft):**	2.5
Location:	M-21-I	**Station:**	0
Date Sampled:	9/1/2020	**Date Tested:**	10/7/2020

R-Value at 300 psi exudation pressure = **11**



Test No.	Compact. Press. (psi)	Density (pcf)	Moist. (%)	Horizont. Pressure (psi)'@ 160 psi	Sample Height (in).	Exud. Pressure (psi)	R Value	R Value Correct.
1	350	115.0	14.0	120	2.46	420	18	18
2	350	114.7	16.0	131	2.47	321	13	13
3	350	113.6	18.0	144	2.48	220	7	7

Sampled by: CW **Tested by:** Kyle Lyons **Checked by:** M.A

Rev. 08-16-2018