Geotechnical and Pavement Investigation Report
MESA-16-Q.5 Bridge Replacement
Mesa County, Colorado

Yeh Project No.: 218-192
March 25, 2019
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1. **Purpose and Scope of Study**

This report presents the results of our geotechnical engineering investigation for foundation and pavement design; and construction of the MESA-16-Q.5 Bridge replacement across the Government Highline Canal in Mesa County, Colorado. The project site is located adjacent to 16 Road, approximately 0.4 mile north of Q Road, as shown in Figure 1 at the end of this report. The purpose of this study was to evaluate geotechnical characteristics of the on-site soils and provide geotechnical recommendations for the proposed bridge replacement.

The geotechnical investigation consisted of field reconnaissance and exploratory test hole drilling to investigate subsurface conditions. Test hole drilling was observed by a representative of Yeh and Associates (YA). Samples obtained during the field exploration were examined by the project personnel and representative samples were selected for laboratory testing to evaluate the engineering characteristics of materials encountered. This report summarizes our field investigation, the results of our analyses, and our conclusions and recommendations for foundations and pavement based on the proposed construction, site reconnaissance, subsurface investigation, and results of the laboratory testing.

2. **Proposed Construction**

A new road alignment and bridge with associated structures along 16 Road has been proposed across the Government Highline Canal. The proposed bridge will replace the existing bridge across the canal. Based on preliminary plans provided by the client, the new single span bridge structure will have a width of approximately 60 feet and a length of 62 feet. The proposed bridge is to include two 11-foot wide lanes, each lane with 4-foot wide shoulders included in 17.5-foot clear zones. The proposed bridge abutments will likely be founded on drilled shafts or shallow foundation systems. New pavement will be included for the realignment of 16 Road.

3. **Site Conditions and Geological Setting**

3.1 Site Conditions

The project site includes the right-of-way of 16 Road from approximately 600 feet south of the existing MESA-16-Q.5 Bridge on 16 Road to approximately 1,000 feet north of the bridge. At the time of this investigation, 16 Road was asphalt pavement in fair condition with some longitudinal cracking and tire rutting as shown in Photo 1. The existing bridge is a single span steel girder
bridge approximately 28 feet wide and 41 feet long that was built in 1975 and reconstructed in 1992. Existing bridge foundations are 6-foot wide spread footings bearing at approximately 9 feet below the pavement grade. The site was bordered by residential farmland to the southwest and southeast, and vacant public lands to the north. The Government Highline Canal is located through the middle of the project site, flowing southeast to northwest. The canal concrete liner appears to be in poor condition near the existing bridge as shown in Photo 2. Based on survey data provided to us by the client, the approximate elevation at the project site ranges from 4,733 to 4,758 feet. The ground surface of the project site roadway was gently sloping at grades of two to five percent from north to south. Site drainage was from the northeast down to the southwest. Big Salt Wash intersects the Government Highline Canal approximately 1.7 miles east of the project site and the Colorado River is approximately 6.1 miles to the southwest. Vegetation consisted of irrigated farmland, and native grasses and shrubs.

Photo 1. Transverse cracking and tire rutting near Test Hole P-1, 16 Road looking north
3.2 Geological Setting

The project site is located in the Grand Valley of the Colorado River, northeast of the Uncompahgre Plateau and southwest of the Book Cliffs. The Quaternary age Redlands Fault Complex is approximately seven miles southwest of the project area at the northeast edge of the Uncompahgre Plateau. Based on the 1989 U.S. Geological Survey map by Ellis, and the adjacent geology maps including the 2009 geologic map of the Mack quadrangle by White et al and the 2015 geologic map of the Fruita quadrangle by Livaccari and Hodge, the site is located on the Cretaceous age Smoky Hill Member of the Mancos Shale bedrock that is dipping, or tilted, gently to the north-northeast. The shale bedrock and soils derived from the shale bedrock may contain expansive clays, which can cause stability problems for roads and buildings. Additionally, there is a possibility that evaporite mineral and salt deposits, including sulfates such as gypsum, associated with the Mancos Shale may be present in the soils that underlie the project site. As per the Colorado Geological Survey (CGS) website for corrosive soils, these minerals may be corrosive to buried metal and concrete. Soil corrosivity test results for soils sampled at the project site can be found in Section 8 of this report. Additional surficial deposits include Quaternary age alluvium and artificial, or manmade, fill and disturbed land.

Photo 2. Concrete damage in Government Highline Canal lining below and west of existing bridge, looking south.
Wetland areas mapped by the U.S. National Wetlands Survey include a channel (or canal) within the project area with an emergent wetland crossing 16 Road just south of the existing bridge.

Geologic hazards at the site include seasonal flooding and mud flows from Government Highline canal, local streams and washes located in and around the project site. Additional soil hazards include swelling soils, collapsible and compressible soils in flooding areas, and corrosive soils and swelling soils derived from the Mancos Shale. Potential flooding should be anticipated within the project site and considered in proposed construction.

4. **Subsurface Investigation**

Five test holes were drilled November 29 and 30, 2018, by HRL Compliance Solutions out of Grand Junction with a CME 55 rubber track rig, using 4-inch solid stem auger drilling and HQ3 wire-line coring systems. Test holes were located in the field by YA using measurements from features shown on plans provided by the client and Mesa County. Test holes were auger drilled or cored to depths ranging from 6 to 51 feet for the proposed improvements. Two test holes were drilled for bridge foundation structures and three test holes were drilled for pavement design analysis. Test hole A-1 was located on the south abutment of the proposed Government Highline Canal Bridge at 16 Road, approximately 16 feet south of the canal and 9 feet east of an existing cattle guard. Test hole A-2 was located on the north abutment of the proposed bridge, approximately 8 feet east of the 16 Road edge of asphalt and 18 feet north of the canal. Three pavement test holes were drilled in the 16 Road right-of-way, with one located in the existing pavement approximately 560 feet south of the proposed bridge at station 15+61 approximately 6 feet left (6L) of new center line. The other two pavement test holes were located in native material along the proposed realignment of 16 Road with one approximately 640 feet north of the proposed bridge at station 3+60,10R and the other approximately 160 feet south at station 11+59,9L.

The two bridge foundation test holes were advanced using 4-inch solid stem auger to depths of 12 and 16 feet, where HQ3 wire-line coring was performed through the augered hole. A minimum of 15 feet of penetration into competent bedrock was achieved at bridge structure test hole locations, to total drilling depths of 38 feet and 51 feet below ground surface. Three test holes drilled for pavement design were advanced to depths of 6 to 10 feet using a 4-inch solid
stem auger. The approximate locations of the test holes are presented on Figure 2 at the end of this report.

At selected intervals, a modified California sampler with a 2-inch interior diameter (ID) and 2.5-inch outside diameter (OD), or a standard split spoon sampler with a 1⅜-inch ID and 2-inch OD were driven into the subsurface materials to record blow counts and obtain samples. The sampler was seated at the bottom of the test hole, then advanced by a 140-pound hydraulic automatic, or “auto,” hammer falling a distance of 30 inches. The number of blows required to drive the sampler two 6-inch intervals or a fraction thereof, constitutes the N-value. The N-value, when properly evaluated, is an index of the consistency or relative density of the material tested.

Samples obtained during the field explorations were examined by the project engineer and representative samples were submitted for laboratory testing to evaluate the engineering characteristics of materials encountered. Representative HQ3 size, 2-3/8-inch diameter core samples from test holes A-1 and A-2 were retrieved for testing. In addition, bulk samples of auger cuttings were obtained at appropriate depths from all test holes. A sample for moisture/density testing (Proctor) was obtained by hand excavation near Test Hole P-2. Test hole logs and legend are presented in Appendix A, an engineering geology sheet is provided in Appendix B, and laboratory test results and core photos can be found in Appendix C.

4.1 Subsurface Conditions

Abutment test holes encountered up to 3 inches of road base over nil to 1.3 feet of gravel fill, 2.8 to 5.7 feet of clay or clay and gravel, over 16.5 to 20.5 feet of brown to dark gray weathered shale on top of more competent black shale to the depths drilled. Two of the pavement design test holes encountered up to 4 inches of topsoil over nil to 1.8 feet of clay over brown to dark gray weathered shale to depths drilled. The third pavement test hole encountered 5 inches of asphalt over 3 inches of road base over 1.3 feet of native sand on top of weathered shale to depth drilled. Table 1 summarizes test hole depths, elevation, location and road surface information.
Table 1 – Test Hole Summary

<table>
<thead>
<tr>
<th>Test Hole Number</th>
<th>Elevation of Test Hole (feet)</th>
<th>Test Hole Depth (feet)</th>
<th>Pavement Thickness (inches)</th>
<th>Road Base Thickness (inches)</th>
<th>Test Hole Location on 16 Road (new alignment stationing)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A-1</td>
<td>4,744.5</td>
<td>38</td>
<td>n/a</td>
<td>3</td>
<td>Proposed south abutment, Sta.10+33,5R</td>
</tr>
<tr>
<td>A-2</td>
<td>4,746.5</td>
<td>51</td>
<td>n/a</td>
<td>2</td>
<td>Proposed north abutment, Sta. 9+55,7L</td>
</tr>
<tr>
<td>P-1</td>
<td>4,733.0</td>
<td>6</td>
<td>5</td>
<td>3</td>
<td>Northbound lane, Sta. 15+61,6L</td>
</tr>
<tr>
<td>P-2</td>
<td>4,738.0</td>
<td>10</td>
<td>n/a</td>
<td>n/a</td>
<td>East of existing pavement, Sta. 11+59,9L</td>
</tr>
<tr>
<td>P-3</td>
<td>4,758.5</td>
<td>9</td>
<td>n/a</td>
<td>n/a</td>
<td>South of existing pavement, Sta. 3+60,10R</td>
</tr>
</tbody>
</table>

4.1.1 Native Clay

One native clay sample tested in the laboratory had 89 percent fines (material passing the No. 200 Sieve). Atterberg limits testing on this sample and one other clay sample indicated liquid limits of 39 percent and plasticity indices of 18 and 23 percent. One clay sample from a depth of 3.0 feet, exhibited a swell of 0.8 percent when wetted under an applied pressure of 1,000 psf (pounds per square foot). The native clay classified as CL based on the Unified Soil Classification System (USCS) and as A-6 (20) based on the American Association of State Highway and Transportation Officials (AASHTO). Proctor test results indicate the native has a maximum dry density of 119.2 pcf at an optimum moisture content of 13.6 percent when tested in accordance with AASHTO T-180.

A bulk clay sample from test hole P-2 taken at depths of 0.5 to 1.5 feet was subjected to Hveem testing (ASTM 2844) and resulted in an R-value of 12 at an exudation pressure of 300 psi (pounds per square inch).

4.1.2 Native Sand

One native sand sample tested had 28 percent fines, a liquid limit of 24 and a plasticity index of 8. The sample classified as SC (USCS), and as A-2-4 (AASHTO).

4.1.3 Weathered Shale Bedrock

Nine weathered shale samples were subjected to laboratory testing. Atterberg limits testing on two weathered shale samples showed liquid limits of 40 and 42 percent and plasticity indices of 15 and 21 percent. Four weathered shale samples from depths of 1 to 9 feet were tested for swell/consolidation under wetting and an applied load based on the proposed construction for the area. One sample from a depth of 1 foot exhibited a swell of 1.8 percent when wetted under an applied pressure of 200 psf. Three other samples from depths of 6 to 9 feet exhibited swell values ranging from 0.2 to 0.7 percent when wetted under an applied pressure of 1,000 psf.
A bulk sample of weathered shale from test hole P-3 was taken at depths of 0.5 to 1.5 feet and was subjected to Hveem testing (ASTM 2844), resulting in an R-value of 22 at an exudation pressure of 300 psi.

Two core samples of weathered shale from test holes A-1 and A-2 at depths of 18 feet and 13 feet showed unconfined compressive strengths of 8,855 psf and 30,477 psf, respectively. Rock Quality Designation (RQD) values in cored weathered shale in test holes A-1 and A-2 ranged from 0 to 30 percent.

**4.1.4 Competent Shale Bedrock**

Four core samples of apparently competent black shale bedrock from test holes A-1 and A-2 at depths of 23 to 49.5 feet showed unconfined compressive strengths of 282,896 psf to 518,300 psf. RQD values in cored, competent shale in test holes A-1 and A-2 ranged from 75 to 100 percent.

**5. GROUNDWATER**

Groundwater was encountered in test holes A-1 and A-2 at 18.5 and 20.0 feet below surface grade, respectively, when checked after drilling. Groundwater was not encountered in pavement test holes. Variations in groundwater conditions may occur seasonally. The magnitude of the variation will be largely dependent upon the condition of the Government Highline Canal liner, water fluctuations in the canal, and nearby streams and washes, the amount of spring snowmelt, duration and intensity of precipitation, flood irrigation and canals, and the surface and subsurface drainage characteristics of the surrounding area.

**5.1 Seismic Considerations**

The proposed bridge crossing the Government Highline Canal at MESA-16-Q.5 is located at approximately latitude 39.26 degrees north and longitude -108.76 degrees west. Based on the Open File Report 09-04 notes for the adjacent 2009 Geologic Map of the Fruita quadrangle, the U.S. Geological Survey (USGS) has rated Mesa County as having a low to moderate earthquake hazard. Minor seismic activity has been recorded near the project area. A moderate earthquake of magnitude 3.7 occurred on January, 30, 1975 in an area approximately 6 miles east of the project area. According to the USGS and the CGS Fault and Fold Map Server, this earthquake was attributed to an unknown fault. No current active faults are known to exist in the immediate vicinity of the proposed 16 Road improvements. The area of the proposed structure
can be classified as Site Class C, based on material encountered during drilling. The area of the proposed structure can be classified as a Seismic Zone 1 based on similar structures in the area.

Seismic design parameters were determined using the seismic design program from the USGS website. For the proposed bridge, the seismic design parameters for Site Class B Reference Site, and Site Class C values are shown below in Tables 2 and 3.

<table>
<thead>
<tr>
<th>Table 2 – Seismic Design Parameters for Site Class B Reference Site</th>
</tr>
</thead>
<tbody>
<tr>
<td>PGA (0.0 sec)</td>
</tr>
<tr>
<td>0.076 g</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Table 3 – Seismic Design Parameters for Site Class C</th>
</tr>
</thead>
<tbody>
<tr>
<td>$A_s$ (0.0 sec)</td>
</tr>
<tr>
<td>0.091 g</td>
</tr>
</tbody>
</table>

6. **Bridge Foundation Recommendations**

The proposed bridge abutments may be supported on spread footings or drilled shafts (referred to locally as caissons). Spread footings would be relatively easy to construct, do not require a specialty drilling contractor, and would be similar to the existing bridge foundations. Deep excavations would be required. Construction of drilled shafts will require less excavation than spread footings. However, a specialty drilling contractor will be needed. Driven piles would require pre-drilling to be able to penetrate the competent bedrock layer, and are therefore not recommended for this project. Recommendations for the spread footings are presented in Section 6.1, and the drilled shaft recommendations are provided in Section 6.2.

The soil and bedrock properties were estimated from penetration resistance (N-value), material descriptions, and laboratory data. The design and construction of the foundation elements should comply with all applicable requirements and guidelines listed in AASHTO Load Resistance Factored Design (LRFD) Bridge Design Specifications (2017). An Allowable Stress Design (ASD) bearing value is also provided.

Proposed bridge abutment test hole depths, elevation, and approximate depths to weathered and competent shale bedrock are presented in Table 4 below. Elevations are based on a survey provided by the client.
Table 4 – Bridge Abutment Test Hole Bedrock Summary

<table>
<thead>
<tr>
<th>Test Hole Number and Location</th>
<th>Elevation of Test Hole (feet)</th>
<th>Depth to Weathered Bedrock (feet)</th>
<th>Approximate Elevation top of Weathered Bedrock (feet)</th>
<th>Depth to Competent Bedrock (feet)</th>
<th>Approximate Elevation top of Competent Bedrock (feet)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A-1 South abutment</td>
<td>4,744.5</td>
<td>6.5</td>
<td>4,738.0</td>
<td>23.0</td>
<td>4,721.5</td>
</tr>
<tr>
<td>A-2 North abutment</td>
<td>4,746.5</td>
<td>3.5</td>
<td>4,743.0</td>
<td>24.0</td>
<td>4,722.5</td>
</tr>
</tbody>
</table>

6.1 Shallow Foundation – Spread Footing Recommendations

Spread footing foundations can be used to support the MESA-16-Q.5 Bridge at the Government Highline Canal crossing. Based on the laboratory findings, the weathered shale is slightly to moderately expansive. Therefore, there is a risk of differential movement if foundation soils become wet. If the client accepts this risk, a shallow foundation for bridge abutments may be used if the recommendations below are followed.

The design of spread footings at the strength limit state should consider the nominal bearing resistance, eccentric load limitations (overturning), sliding, uplift, and constructability. The design should follow Section 10.6 in the AASHTO LRDF Bridge Design Specifications, 8th Edition (2017). We recommend the following design and construction details:

1. Spread footing foundations should bear in the weathered shale or competent shale bedrock below the sandy clay overburden soils. Natural loose material below foundations should be removed and replaced.
2. Foundations should be protected from frost action. Footings should be placed a minimum of 3 feet below exterior grade to provide adequate frost protection. Abutment footings should bear on hard weathered shale encountered at a depth of approximately 10 feet below the existing ground surface.
3. A nominal bearing resistance of $q_n = 30$ ksf is recommended (per AASHTO equation 10.6.3.1.2a-1). Abutment footings should have a minimum effective footing width of 4 feet. Footings for wing walls and other structures should have a minimum width of 2 feet. A resistance factor of 0.45, per Table 10.5.5.2.2-1 in AASHTO (2017), should be applied to the nominal bearing resistance.
4. For Allowable Stress Design (ASD) criteria, shallow spread footing foundations can be designed for a maximum allowable soil pressure of $q_a = 10$ ksf.

5. Our recommendations consider that the foundation bearing materials could become wet due to flooding or leaks of the Government Highline Canal. Foundations should bear below the anticipated depth of scour.

6. A minimum thickness of 6 inches of granular material should be placed below the bottoms of footings to increase resistance to sliding. A cohesion of 1 ksf should be used to calculate sliding resistance per AASHTO Section 10.6.3.4. Passive pressure to resist sliding can be estimated based on equivalent fluid densities presented in Section 6.3. Use a resistance factor of 0.85 friction resistance and a factor of 0.50 for passive resistance (per AASHTO 10.5.5.2.2-1).

7. All foundation excavations should be observed by a representative of the geotechnical engineer prior to placement of concrete.

8. The existing bridge (northwest of this proposed location) appears to be supported on spread footings at $D_f = 9$-feet. The existing foundation and structures should be completely removed down 1 foot below natural ground surface prior to the placement of the new footings at the proposed bridge site. Unless otherwise directed by Mesa County, adjacent structures not impeding new construction may be left in place.

6.2 Drilled Shaft Recommendations

6.2.1 Drilled Shaft Nominal Axial Resistance

The bearing resistance of drilled shafts will be developed from side and tip resistance in the underlying weathered and competent shale bedrock. The resistance from the overburden soil should be neglected. The weathered shale encountered in the abutment test holes can be described as an argillaceous geomaterial. Drilled shafts should bear in the very hard unweathered shale. Depth of penetration below the weathered shale should be at least $1.5 \times D$ (where $D$ is the diameter of the shaft). Design should be per AASHTO 10.8.3.5.4b (2017). In areas where rock coring produced suitable core recovery (RQD was greater than 50 percent), axial resistance was calculated using design methods based on the unconfined compressive strength of the rock using AASHTO 10.8.3.5 (2017). The expansive potential of the clay overburden soils is classified as marginal per Table 10.4.6.3-1 of the AASHTO LRFD specifications. The expansive potential of the weathered bedrock and competent bedrock is classified as low. Side resistance from shaft penetration through the weathered shale and into
the competent shale is expected to be sufficient to offset any uplift due to swelling of clay overburden or adjacent weathered bedrock.

Table 5 contains the recommended values for the nominal side and tip resistance for drilled shafts founded in the underlying weathered and competent shale bedrock. The upper three feet of weathered 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 (3) diameters from center-to-center.

<table>
<thead>
<tr>
<th>“Hard” Argillaceous Geomaterial (50&lt;N&lt;80 or 10ksf&lt;UCCS&lt;100ksf)</th>
<th>“Very Hard” Competent Shale (N&gt;80+ or UCCS&gt;100 ksf)</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.33</td>
<td>1,293</td>
</tr>
</tbody>
</table>

### 6.2.2 Drilled Shaft Axial Resistance Factors

Based on Section 10.5.5.2.4-1 in AASHTO (2017), a resistance factor of 0.60 should be used for the side resistance and resistance factor of 0.55 can be used for the tip resistance.

### 6.2.3 Drilled Shaft Lateral Resistance

The input parameters provided in Table 6 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 6 provides the estimated values associated with the soil types encountered in the borings. The nature and type of loading should be considered carefully. The values in Table 6 may need to be revised for foundation elements that are relatively close to a retaining wall.

Individual soil layers and their extent can be averaged or distinguished by referring to the boring logs at the locations of the proposed foundations. 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 3 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 (2017). 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 6 – LPILE Parameters

<table>
<thead>
<tr>
<th>Soil Type</th>
<th>LPILE Soil Criteria</th>
<th>Effective Unit Weight (pcf)</th>
<th>Friction Angle, φ (deg.)</th>
<th>Cohesion, c (psf)</th>
<th>Strain Factor, $\varepsilon_{50}$</th>
<th>p-y modulus $k_{static}$ (pci)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>AGT</td>
<td>BGT</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Native Clay</td>
<td>Stiff Clay w/o Free Water (Welch &amp; Reese)</td>
<td>115</td>
<td>52.5</td>
<td>24</td>
<td>500</td>
<td>0.01</td>
</tr>
<tr>
<td>Weathered Bedrock</td>
<td>Stiff Clay w/o Free Water (Welch &amp; Reese)</td>
<td>125</td>
<td>62.5</td>
<td>24</td>
<td>1,000</td>
<td>0.008</td>
</tr>
<tr>
<td>Competent Bedrock</td>
<td>Hard Clay w/o Free Water (Welch &amp; Reese)</td>
<td>135</td>
<td>135</td>
<td>-</td>
<td>8,000</td>
<td>0.001</td>
</tr>
</tbody>
</table>

**Notes**

1. AGT is an abbreviation for above groundwater table, BGT is an abbreviation for below groundwater table.

### 6.2.4 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 depth. 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 inches when designed according to the criteria presented in this report.

5. A representative of the geotechnical engineer should observe drilled shaft installation operations on a full-time basis.

### 6.3 Lateral Earth Pressure

Bridge retaining/wing walls should be designed to resist lateral earth pressures. We recommend all retaining/wing walls be backfilled with properly compacted Class 1 Structure Backfill meeting the requirements in the Colorado Department of Transportation, Standard Specifications for Road and Bridge Construction (CDOT Specifications). Walls can be designed using an equivalent fluid density of 38 pcf for active pressures or 60 pcf for at rest conditions for Class 1 Structure Backfill. On-site materials should not be used for retaining/wing wall backfill because the clayey material has swell potential. This equivalent fluid density assumes a horizontal slope above the wall. This value also assumes that the backfill materials are not saturated. Wall designs should consider the influence of surcharge loading such as traffic, construction equipment and/or sloping backfill.

Retaining/wing walls should be constructed with a drainage system to prevent buildup of hydrostatic pressure immediately behind the wall. Drainage systems such as free-draining gravel, pipes, drain board and/or weep holes are commonly used for the wall drainage. Water levels during canal operation may make subsurface drains impractical. Walls should be designed for the anticipated hydrostatic pressures where drains cannot be provided.

### 6.4 Bridge Approach Embankment

Based on laboratory testing, weathered bedrock encountered at the project site may be expansive when exposed to water. We recommend fill material consist of imported Class 1 Structural Backfill, per CDOT Standard Specifications. The upper 2 feet of embankment material should have an R-value of at least 30 to support the pavement structure. We anticipate post-construction settlements of up to 1-inch under these conditions.
7. PAVEMENT RECOMMENDATIONS

7.1 Subgrade Strength

R-values of 12 and 22 were obtained from representative samples of shallow subgrade soils at the project site. The tested materials were sampled from clay and weathered shale encountered in test holes P-2 and P-3, respectively, at depths of 0.5 to 1.5 feet. The R-value of 12 was used to calculate a resilient modulus of 3,803 psi for use in the pavement section design. The modulus value was used as one of the inputs for the DARWin Pavement Design and Analysis computer program to determine recommended pavement thickness.

Other structural layer coefficients used in design were found in the Colorado Department of Transportation 2014 Pavement Design Manual.

7.2 Traffic Loading

The traffic loading was determined using an Average Daily Traffic (ADT) of 268 vehicles per day, based on a 20% growth rate and a current ADT of 244. Traffic counts were obtained from Mesa County. Twenty-year projected volumes were used as an input for the design of hot mix asphalt (HMA) pavement. The resulting traffic ESAL (Equivalent Single Axle Load applications) values were estimated at 100,000 for HMA pavement. The data and calculations of the traffic loading ESAL values are presented in Appendix D.

7.3 Design Assumptions and Inputs

Table 7 presents the input design parameters used for the design of all flexible pavement sections.

<table>
<thead>
<tr>
<th>Table 7 - Flexible Pavement Design Parameters</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>HMA Design Inputs</strong></td>
</tr>
<tr>
<td>Initial Serviceability 4.5</td>
</tr>
<tr>
<td>Terminal Serviceability 2.0</td>
</tr>
<tr>
<td>Reliability Level, % 95</td>
</tr>
<tr>
<td><strong>Structural Numbers</strong></td>
</tr>
<tr>
<td><strong>Pavement</strong></td>
</tr>
<tr>
<td>HMA Traffic Loading</td>
</tr>
</tbody>
</table>
7.4 Pavement

A pavement section is a layered structure designed to disperse dynamic traffic loads to the subgrade. The performance of the pavement structure depends on the traffic loadings and physical properties of the subgrade materials. The recommended pavement design thickness sections are summarized below. Recommended HMA pavement thickness can be found in Table 8.

HMA pavement design calculations were performed using the program DARWin Version 3.1. The program follows the guidelines from the 1993 AASHTO Pavement Design Guide and also the 2014 CDOT Pavement Design Manual.

The program outputs for all pavement designs are presented in Appendix E.

<table>
<thead>
<tr>
<th>Pavement Type</th>
<th>Required SN</th>
<th>New HMA (inches)</th>
<th>Class 6 Aggregate Base Course (inches)</th>
<th>Calculated SN</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alternate A</td>
<td>3.17</td>
<td>4.5</td>
<td>10.0</td>
<td>3.18</td>
</tr>
<tr>
<td>Alternate B</td>
<td></td>
<td>5.0</td>
<td>9.0</td>
<td>3.28</td>
</tr>
<tr>
<td>Alternate C</td>
<td></td>
<td>6.0</td>
<td>5.0</td>
<td>3.24</td>
</tr>
</tbody>
</table>

Based on the DARWin program Version 3.1 (1993 AASHTO) computer program, an HMA pavement thickness of 5.0 inches overlying 9.0 inches of aggregate base course would be acceptable for the new alignment of 16 Road. A layer of pit run (CDOT ABC Class 3) can be used to improve subgrade conditions. Removal of the upper 12 inches of native soil subgrade and replacement with CDOT Aggregate Base Course (Class 3) will reduce the required pavement section thicknesses to 3 inches HMA surface course over 6 inches Class 6 aggregate base course.

7.5 Hot Mix Asphalt Type

A printout from the LTPPBind program is presented following the pavement designs in Appendix E. The data from the LTPPBind program, based on local weather data, recommends that performance graded binder PG 64-28 be used in the project area. For the HMA mix we recommend a nominal 0.5 inch mix conforming to CDOT Grading SX(75) containing the above performance graded binder; PG 64-28. A locally produced mix that is approved for use on CDOT projects in the area can be substituted for the recommended HMA mix.
Aggregates for hot plant mix bituminous pavement should be of uniform quality, and composed of clean, hard, durable particles of crushed stone, gravel, or slag. Excess of fine material should be wasted before crushing.

### 7.6 Pavement Preparation

In order to prepare the subgrade for the placement of the new pavements, we recommend removal of any existing fill soils and topsoil material prior to construction. Following removal of the existing fill soils and topsoil, the native subgrade should be reconditioned by scarifying and recompacting to a minimum depth of 8 inches. Stabilization, either mechanical or chemical, of the existing subgrade may be necessary in order to achieve a stable paving subgrade. These recommendations can be provided during construction if necessary. Subgrade deterioration in areas of frequent construction traffic should be anticipated and stabilization methods such as imported layers of pit run material, or geogrid stabilization, may be necessary. We recommend the placement of a separation geotextile conforming to AASHTO M288 Class 1 Grade 1 on the compacted subgrade prior to placement of the ABC.

### 8. WATER SOLUBLE SULFATE AND CORROSION TESTING

Three weathered shale samples taken in abutment test holes at depths of 6 feet, 13 feet, and 18 feet were tested for water soluble sulfates. The concentration of water-soluble sulfates measured in the laboratory ranged from 0.023 percent to 0.29 percent. The concentration of soluble sulfate in the soil samples for this project represent a susceptibility to sulfate attack to concrete of Class 2 based on Table 601-2 of the 2017 CDOT Standard Specifications for Road and Bridge Construction. Concrete mixes in contact with soils on this project should meet the requirements for Class 2 in conformance with Section 601.04 of the CDOT Standard Specifications. When applicable, a layer of structural fill or aggregate base course could be used as a separator between concrete and native material. Structural fill and aggregate base course are assumed to have Class 0 exposure, or no effect on concrete.

The pH, electrical resistivity and water-soluble chloride concentration were also determined for the three samples. Test results measured pH values of 7.5 to 7.9, resistivity values of 539 to 1,133 ohm-centimeters, and water-soluble chlorides measured from 0.0010 to 0.0035 percent. A qualified corrosion engineer should review this data to evaluate the appropriate level of corrosion protection for subgrade utilities and buried metal structures proposed for the area.
9. LIMITATIONS

This study was conducted in accordance with generally accepted geotechnical engineering practices in this area for use by the client for feasibility of proposed construction. Recommendations herein are intended to be used for design by a qualified structural engineer. The preliminary analyses and recommendations presented in this report are based upon our data obtained from limited field observations, widely spaced test holes, laboratory testing, our understanding of the proposed construction and other information as discussed in this report. It is possible and likely that subsurface conditions may vary from those encountered in the test holes. We should also review the design for conformance to the recommendations in the report when the scope of the proposed construction, including the proposed loads, finished elevations or structure locations, become established.

The scope of services for this project did not include, specifically or by implication, any environmental or biological (e.g., mold, fungi, and bacteria) assessment of the site or identification or prevention of pollutants, hazardous materials or conditions or biological conditions. If the owner is concerned about the potential for such contamination, conditions or pollution, other studies should be undertaken.

The report was prepared in substantial accordance with the generally accepted standards of practice for geotechnical engineering as exist in the site area at the time of our investigation. No warranties, express or implied, are intended or made. The recommendations in this report are based on the assumption that Yeh and Associates will conduct an adequate program of construction testing and observation to evaluate compliance with our recommendations.
10. REFERENCES


Colorado Department of Transportation Standard Specifications for Road and Bridge Construction, CDOT 2017.


MESA-16-Q.5 Bridge Improvements
Mesa County, Colorado

Site Location Map

Base maps acquired from maps.google.com and Google Earth
APPENDICES

APPENDIX A - TEST HOLE LOGS AND LEGEND
APPENDIX B - ENGINEERING GEOLOGY SHEET
APPENDIX C - LABORATORY RESULTS AND CORE PHOTOGRAPHS
APPENDIX D - ESALs AND TRAFFIC LOADING CALCULATIONS
APPENDIX E - PAVEMENT DESIGN
Appendix A

TEST HOLE LOGS AND LEGEND
Legend for Symbols Used on Borehole Logs

Sample Types
- Auger Cuttings
- Rock Core
- Modified California Sampler (2.5 inch OD, 2.0 inch ID)
- Standard Penetration Test (ASTM D1586)

Other Symbols
- Groundwater level taken after drilling, December 2018

Lithology Symbols (see Boring Logs for complete descriptions)
- Hot Mix Asphalt (HMA)
- Road Base
- Topsoil
- FILL GRAVEL, clayey
- CLAY
- SAND, clayey
- GRAVEL, clayey
- Weathered Shale Bedrock (Intermediate Geomaterial-Argillaceous)
- SHALE

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

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/Consolidation (ASTM D4546)
- UCCS: Unconfined Compressive Strength (ASTM D2166)
- 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. “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.

2. 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.
18 ft - Start solid stem auger drilling  

8.0 ft - Stiffer drilling  

16.0 ft - Switch to HQ Core

**Soil Samples**

- **Elevation (feet):** 5 ft  
- **Material Description:** 0.0 - 0.3 ft, 3 inches, (road base).

- **Elevation (feet):** 6-8 ft  
- **Material Description:** 0.3 - 1.3 ft, clayey GRAVEL, brown with orange, damp, loose, subangular, (fill).

- **Elevation (feet):** 10 ft  
- **Material Description:** 1.3 - 6.5 ft, CLAY, brown, medium plasticity, damp, stiff, calcareous with gypsum deposits.

- **Elevation (feet):** 15-20 ft  
- **Material Description:** 6.5 - 23.0 ft, WEATHERED SHALE, brown to dark brown, decomposed to moderately weathered, extremely soft to hard, fissile medium plasticity; gypsum deposits, damp to wet.

- **Elevation (feet):** 20-22 ft  
- **Material Description:** Gray to dark gray, moderately weathered, hard, fissile brittle.

- **Elevation (feet):** 25-30 ft  
- **Material Description:** Brown to dark gray, decomposed to predominantly decomposed, hard, iron staining, light brown clay infilling.

- **Elevation (feet):** 30-35 ft  
- **Material Description:** 19.5 - 20.0 ft, clay infilling, rubblized zone.

- **Elevation (feet):** 35-38 ft  
- **Material Description:** 20.8 - 21.2 ft, dark gray, decomposed, clay infilling.

- **Elevation (feet):** 38-40 ft  
- **Material Description:** 22.0 - 22.5 ft, clay infilling, rubblized zone.

- **Elevation (feet):** 40-42 ft  
- **Material Description:** 23.0 - 38.0 ft, SHALE, black, slightly weathered to fresh, very hard, calcite infilling, partings in lamination; few moderate angle healed fractures.
### Project Name:
MESA-16-Q.5 Bridge Replacement

### Project Number:
218-192

### Boring No.:
A-1

<table>
<thead>
<tr>
<th>Elevation (feet)</th>
<th>Depth (feet)</th>
<th>Sample Type/Advancement Method</th>
<th>Rock Recovery (%)</th>
<th>Soil Samples Recovery (%)</th>
<th>Blows per 6 in</th>
<th>Penetration Resistance</th>
<th>Lithology</th>
<th>Material Description</th>
<th>Moisture Content (%)</th>
<th>Dry Density (pcf)</th>
<th>Fines Content (%)</th>
<th>Plasticity Index</th>
<th>AASHTO &amp; USCS Classifications</th>
<th>Field Notes and Other Lab Tests</th>
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<tbody>
<tr>
<td>4715</td>
<td>30</td>
<td></td>
<td>95</td>
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<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4710</td>
<td>35</td>
<td></td>
<td>100</td>
<td>100</td>
<td></td>
<td></td>
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<td>100</td>
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<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
</tbody>
</table>

Bottom of Hole at 38.0 ft.

UCCS=282896psf
### Boring Log

**Project Name:** MESA-16-Q.5 Bridge Replacement  
**Project Number:** 218-192  
**Boring No.:** A-2

**Boring Began:** 11/29/2018  
**Boring Completed:** 11/29/2018  
**Weather Notes:** Cloudy, 30's, rain

**Drilling Method(s):** Solid-Stem Auger (4" OD) / Coring  
**Drill Rig:** CME 55 Rubber Track  
**Driller:** HRL Compliance  
**Hammer:** Automatic (hydraulic), ER: %

**Total Depth:** 51.0 ft  
Inclination from Horiz.: Vertical

**Coordinates:** N: 1.0  E: 4.0  
**Location:** North abutment; 5' E of 16 Road EOA, 18' N of Highline Canal; ~Sta. 9+55, 7L

**Logged By:** J. O’Rear & J. Mulumba  
**Final By:** J. Mulumba / S. White

**Ground Elevation:** 4746.5 ft  
**Coordinates:** N: 1.0  E: 4.0

**Weather Notes:** Cloudy, 30's, rain

#### Soil Samples

<table>
<thead>
<tr>
<th>Elevation (feet)</th>
<th>Depth (feet)</th>
<th>Sample Type/ Advancement Method</th>
<th>Rock</th>
<th>Soil Samples</th>
<th>Recovery (%)</th>
<th>Penetration Resistance Blows per 6 in</th>
<th>Lithology</th>
<th>Material Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>4745</td>
<td>0.0 - 0.2 ft.</td>
<td>2 inches Road Base.</td>
<td>6-6</td>
<td>12</td>
<td></td>
<td></td>
<td></td>
<td>0.2 - 3.0 ft. CLAY with weathered shale, brown, medium plasticity, damp, stiff, angular shale pieces, calcareous.</td>
</tr>
<tr>
<td>4740</td>
<td>0.2 - 3.0 ft.</td>
<td>CLAY</td>
<td>6-10</td>
<td>16</td>
<td></td>
<td></td>
<td></td>
<td>3.0 - 3.5 ft. clayey GRAVEL brown, medium plasticity, damp, medium dense, subangular.</td>
</tr>
<tr>
<td>4735</td>
<td>3.5 - 24.0 ft.</td>
<td>WEATHERED SHALE</td>
<td>13-20</td>
<td>33</td>
<td></td>
<td></td>
<td></td>
<td>3.5 - 24.0 ft. WEATHERED SHALE brown to dark brown, decomposed to moderately weathered, medium hard to hard, fissile open fractures, clay infilling, medium plasticity; gypsum deposits; damp to wet. Decomposed, medium hard, less gypsum.</td>
</tr>
<tr>
<td>4730</td>
<td>Dark brown, predominantly decomposed, hard.</td>
<td>21-38</td>
<td>59</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4725</td>
<td>12.0 - 16.0 ft.</td>
<td>dark brown to dark gray, decomposed to predominantly decomposed, extremely soft to medium hard, open fractures, clay infilling.</td>
<td>100</td>
<td>0</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4720</td>
<td>16.0 - 23.5 ft.</td>
<td>dark gray, moderately weathered, medium hard to hard, fissile partings in lamination; few moderate angle fractures with clay or calcite infilling.</td>
<td>95</td>
<td>0</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4715</td>
<td>24.0 - 45.0 ft.</td>
<td>SHALE</td>
<td>100</td>
<td>27</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4710</td>
<td>black, slightly weathered to fresh, very hard, lamination healed fractures, calcite infilling, with gypsum.</td>
<td>100</td>
<td>100</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Moisture Content (%):** 3.1  
**Dry Density (pcf):** 154.0  
**Liquid Limit:** 33  
**Plasticity Index:** 95

**Atterberg Limits:**
- **S:** 33  
- **C:** 95  
- **S/C:** 0.3%

**Re:** 1133ohm·cm  
**UCCS:** 30477psf

**Field Notes and Other Lab Tests**

- **Atterberg Limits:**
  - **Symbol:** -  
  - **Depth:** -  
  - **Date:** 12/17/18

- **Groundwater Levels:**
  - **Symbol:** -  
  - **Depth:** 20.0 ft  
  - **Date:** 12/17/18

**Sample Type/ Advancement Method:**
- **BORING LOG 2015 - SPT CDOT STYLE 218-192 LOGS, SW1-3-19.GPJ 2015 YEH ASSOCIATES TEMPLATE.GDT  YEH GINT LIBRARY_10-10-18.GLB 1/4/19

**Consulting Engineers & Scientists:**
- **Yeh and Associates, Inc.**

**Project Number:** 218-192  
**Name:** MESA-16-Q.5 Bridge Replacement

**Sampling:**
- **Sample Type/ Advancement Method:**
  - **BORING LOG 2015 - SPT CDOT STYLE 218-192 LOGS, SW1-3-19.GPJ 2015 YEH ASSOCIATES TEMPLATE.GDT  YEH GINT LIBRARY_10-10-18.GLB 1/4/19

**Hammer:**
- **Automatic (hydraulic), ER:** %

**Drill Rig:**
- **CME 55 Rubber Track**

**Driller:**
- **HRL Compliance**

**Weather:**
- **Cloudy, 30's, rain**

**Coordinates:**
- **N:** 1.0  
- **E:** 4.0

**Elevation:**
- **4746.5 ft**

**Ground Elevation:**
- **4746.5 ft**

**Total Depth:**
- **51.0 ft**

**Inclination from Horiz.:**
- **Vertical**

**Location:**
- **North abutment; 5' E of 16 Road EOA, 18' N of Highline Canal; ~Sta. 9+55, 7L**

**Groundwater Levels:**
- **20.0 ft**

**Symbol:** -  
**Depth:** -  
**Date:** 12/17/18
<table>
<thead>
<tr>
<th>Elevation (feet)</th>
<th>Depth (feet)</th>
<th>Soil Samples</th>
<th>Material Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>4700</td>
<td>30</td>
<td></td>
<td>Fractured zone with clay infilling.</td>
</tr>
<tr>
<td>4705</td>
<td>35</td>
<td></td>
<td>Fractured zone with clay infilling.</td>
</tr>
<tr>
<td>4710</td>
<td>40</td>
<td></td>
<td>37.7 - 40.0 ft. rubblized zone.</td>
</tr>
<tr>
<td>4715</td>
<td>45</td>
<td></td>
<td>Fractured zones with clay infilling; some high angle healed fractures.</td>
</tr>
<tr>
<td>4720</td>
<td>50</td>
<td></td>
<td>45.0 - 45.5 ft. WEATHERED SHALE, black, predominantly decomposed, rubblized.</td>
</tr>
<tr>
<td>4725</td>
<td>51</td>
<td></td>
<td>45.5 - 51.0 ft. SHALE, black, slightly weathered to fresh, very hard, partings in lamination; gypsiferous.</td>
</tr>
<tr>
<td>4730</td>
<td></td>
<td></td>
<td>45.7 - 46.3 ft. vertical healed fractures with calcite infilling.</td>
</tr>
</tbody>
</table>

Bottom of Hole at 51.0 ft.

51.0 ft. - End core
MESA-16-Q.5 Bridge Replacement

Project Name: 218-192

Boring No.: P-1

Boring Began: 11/29/2018
Boring Completed: 11/29/2018
Drilling Method(s): Solid-Stem Auger (4" OD)
Driller: HRL Compliance
Drill Rig: CME 55 Rubber Track
Hammer: Automatic (hydraulic), ER: %

Location: 16 Road NB lane, 3’ west of EOA, ~Sta. 15+61,6L
Coordinates: N: 1.0  E: 1.0
Logged By: J. O'Rear
Final By: J. Mulumba/S. White

Total Depth: 6.0 ft
Ground Elevation: 4733.0 ft
Coordinates: N: 1.0  E: 1.0
Inclination from Horiz.: Vertical
Night Work: ☐

Weather Notes: Partly cloudy

Groundwater Levels: Not Observed

Elevation (feet)  Depth (feet)  Soil Samples  Blows per 6 in  Penetration Resistance  Lithology  Material Description  Moisture Content (%)  Dry Density (pcf)  Gravel Content (%)  Sand Content (%)  Fines Content (%)  Atterberg Limits  AASHTO & USCS Classifications  Field Notes and Other Lab Tests

0.0 - 0.4 ft. 5 inches HMA.
0.4 - 0.7 ft. 3 inches Road Base.
0.7 - 2.0 ft. clayey SAND with gravel, dark brown, low plasticity, dry to damp, medium dense.
2.0 - 6.0 ft. WEATHERED SHALE, brown to dark brown, decomposed to predominantly decomposed, firm to medium hard, fissile medium plasticity.

Bottom of Hole at 6.0 ft.

6.0 ft - End boring, backfill with cuttings and add cold patch asphalt at surface.
**MESA-16-Q.5 Bridge Replacement**

**Project Name:**

**Project Number:** 218-192

**Boring No.:** P-2

---

**Boring Began:** 11/29/2018  
**Boring Completed:** 11/29/2018  
**Drilling Method(s):** Solid-Stem Auger (4" OD)  
**Driller:** HRL Compliance  
**Drill Rig:** CME 55 Rubber Track  
**Hammer:** Automatic (hydraulic), ER: %  

---

**Total Depth:** 10.0 ft  
**Ground Elevation:** 4738.0 ft  
**Coordinates:** N: 1.0  E: 2.0  
**Location:** 20' E of 16 Road EOA, 60' S of power pole:--Sta. 11+59.9L  
**Weather Notes:** Cloudy, 30's  
**Inclination from Horiz.:** Vertical  
**Night Work:**  

---

**Groundwater Levels:** Not Observed

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Depth</th>
<th>Date</th>
<th>Atterberg Limits</th>
<th>AASHTO &amp; USCS Classifications</th>
<th>Field Notes and Other Lab Tests</th>
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<tr>
<td></td>
<td></td>
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</tbody>
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---

**Weather Notes:**  

**Blows per 6 in**  
**Material Description**  
**Penetration Resistance**  
**Soil Samples**  
**Sample Type/ Advancement Method**  
**Lithology**  

<table>
<thead>
<tr>
<th>Elevation (feet)</th>
<th>Depth (feet)</th>
<th>Soil Samples</th>
<th>Blows per 6 in</th>
<th>Lithology</th>
<th>Material Description</th>
<th>Moisture Content (%)</th>
<th>Dry Density (pcf)</th>
<th>Gravel Content (%)</th>
<th>Sand Content (%)</th>
<th>Fine Content (%)</th>
<th>Liquid Limit</th>
<th>Plasticity Index</th>
<th>Atterberg Limits</th>
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<tbody>
<tr>
<td>0.0 - 0.2 ft.</td>
<td>2 inches</td>
<td>Topsoil</td>
<td>5-5</td>
<td>10</td>
<td>6.0</td>
<td>1</td>
<td>10</td>
<td>89</td>
<td>39</td>
<td>23</td>
<td>A-6 (20)</td>
<td>R-Value=12</td>
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<tr>
<td>0.2 - 3.0 ft.</td>
<td>CLAY</td>
<td>brown with orange, medium plasticity, dry to damp, stiff, calcareous.</td>
<td>13-18-21</td>
<td>39</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3.0 - 10.0 ft.</td>
<td>WEATHERED SHALE</td>
<td>brown to dark brown, decomposed to moderately weathered, medium hard to hard, fissile medium plasticity, gypsum deposits.</td>
<td>22-36</td>
<td>58</td>
<td></td>
<td></td>
<td></td>
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<td></td>
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</tbody>
</table>

---

**Bottom of Hole at 10.0 ft.**

10.0 ft. - End boring, backfill with cuttings
**Boring Log**

**Project Name:** MESA-16-Q.5 Bridge Replacement

**Project Number:** 218-192

**Boring No.:** P-3

**Boring Began:** 11/29/2018

**Boring Completed:** 11/29/2018

**Drilling Method(s):** Solid-Stem Auger (4" OD)

**Driller:** HRL Compliance

**Drill Rig:** CME 55 Rubber Track

**Hammer:** Automatic (hydraulic), ER: %

**Ground Elevation:** 4758.5 ft

**Coordinates:** N: 1.0  E: 5.0

**Location:** 15.5’ S of 16 Road EOA, ~Sta. 3+60,10R

**Total Depth:** 9.0 ft

**Weather Notes:** Cloudy

**Inclination from Horiz.:** Vertical

**Night Work:**

**Groundwater Levels:** Not Observed

**Logged By:** J. O’Rear & J. Mulumba

**Final By:** J. Mulumba/S. White

**Elevation (feet)**  
**Depth (feet)**  
**Sample Type/Advancement Method**  
**Soil Samples**  
**Blows per 6 in**  
**Penetration Resistance**  
**Lithology**  
**Material Description**  
**Moisture Content (%)**  
**Dry Density (pcf)**  
**Liquid Limit**  
**Plasticity Index**  
**Atterberg Limits**  
**AASHTO & USCS Classifications**

| Elevation | Depth | Sample Type | Advancement Method | Soil Samples | Blows per 6 in | Penetration Resistance | Lithology | Material Description | Moisture Content (%) | Dry Density (pcf) | Liquid Limit | Plasticity Index | Atterberg Limits | Field Notes and Other Lab Tests |
|-----------|-------|-------------|---------------------|--------------|----------------|------------------------|-----------|----------------------|---------------------|-----------------|--------------|----------------|-----------------|---------------------------|-----------------|
| 4755      | 0.0   |             |                     |              |                |                        |           |                      |                     |                 |              |                |                 |                           |                 |
| 4750      | 5     |             |                     |              |                |                        |           |                      |                     |                 |              |                |                 |                           |                 |
| 4745      | 5     |             |                     |              |                |                        |           |                      |                     |                 |              |                |                 |                           |                 |
| 4740      | 10    |             |                     |              |                |                        |           |                      |                     |                 |              |                |                 |                           |                 |
| 4735      | 15    |             |                     |              |                |                        |           |                      |                     |                 |              |                |                 |                           |                 |

- **0.0 - 0.3 ft.** 4 inches Topsoil, light brown, medium plasticity, dry, very soft, organics, roots.

- **0.3 - 9.0 ft. WEATHERED SHALE**, brown to dark brown, decomposed to predominantly decomposed, residuum to medium hard, fissile medium plasticity, gypsum deposits, calcareous.

- **Bottom of Hole at 9.0 ft.**

- **9.0 ft.** End boring, backfill with cuttings
Appendix B

ENGINEERING GEOLOGY SHEET
MESA 16-Q.5 Bridge Improvements
Mesa County, Colorado

Soil Lithology
- ROAD BASE, 2 to 8 inches.
- FILL GRADE: EL, clayey, damp, loose, su angular, ro: n, 17 ft orange.
- CLAY, occasionally mi ed: 1th: weathered shale, damp, medium plasticity, stiff, angular shale pieces, calcareous, occasionally - 1th gypsite deposits, ro: n.
- GRA: EL, clayey, damp, medium plasticity, medium dense, su angular, ro: n.

Rock Lithology
- WEATHERED SHALE, damp to moist, medium plasticity, e, tremely soft to hard, roller, fissile, decomposed to moderately weathered fractures - 1th iron staining and clay infilling, 1th gypsite, 1.5 ed orna. ro: n, dark ro: n, dark gray.
- SHALE, very hard partings in lamination, gypiferous, needles, slightly, weathered to fresh, heated fractures - 1th caliche infilling, dark,

Graphics
- CLAY, occasionally mixed with weathered shale, damp, medium plasticity, stiff, angular shale pieces, calcareous, occasionally - 1th gypsum deposits, ro: n.
- GRADE: EL, clayey, damp, medium plasticity, medium dense, su angular, ro: n.

Penetration Resistance
- Bi: s per foot - OR - inches of penetration.
- A value of 9: 9 or 9: 9 indicates 50 st s to the sampler, with a penetration of 1 inches.
- A value of 9: 9 or 9: 9 indicates 50 st s to the sampler for the initial 6 inches, and 50 st s with a penetration of 1 inches in the second iteration.

LAB TESTING ABBREVIATIONS
- LL - % Liquid Limit
- PL - % Plastic Limit
- PI - % Plastic Index
- CLAY, occasionally mixed with weathered shale, damp, medium plasticity, stiff, angular shale pieces, calcareous, occasionally - 1th gypsum deposits, ro: n.
- GRADE: EL, clayey, damp, medium plasticity, medium dense, su angular, ro: n.

Rock Quality Designation (RQD)
- Indicates Modified California sample method
- Indicates Solid Stem Auger drilling method
- Indicates Split Spoon sample method

Sample Type
- Core drilling method
- Indicate modified California sample method
- Indicate Split Spoon sample method
- Indicate Solid Stem Auger drilling method

- Typical borings log

SUMMARY OF TEST RESULTS

<table>
<thead>
<tr>
<th>Sample Location</th>
<th>Moisture Content (%)</th>
<th>Dry Density</th>
<th>USCSC</th>
<th>UCSCS</th>
<th>USCSCS</th>
<th>USCSCS</th>
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<tbody>
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<td>A-1</td>
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<td>11.4</td>
<td>114</td>
<td>39</td>
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<td>18</td>
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<td>518</td>
</tr>
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</table>

NOTES:
1. Test hole locations and elevations provided from survey by Collins Engineers, Inc.
2. Bridge layout and design provided by Collins Engineers, Inc.
Appendix C

LABORATORY TEST RESULTS
AND CORE PHOTOGRAPHS
### Summary of Laboratory Test Results

**Project Name:** MESA-16-Q.5 Bridge Replacement

<table>
<thead>
<tr>
<th>Sample Location</th>
<th>Test Hole</th>
<th>Depth (ft)</th>
<th>Sample Type</th>
<th>Moisture Content (%)</th>
<th>Dry Density (pcf)</th>
<th>Gravel &gt; #4 (%)</th>
<th>Sand (%)</th>
<th>Fines &lt; #200 (%)</th>
<th>LL</th>
<th>PL</th>
<th>Pi</th>
<th>Water Soluble Sulfate (%)</th>
<th>Water Soluble Chloride (%)</th>
<th>Resistivity (ohm-cm)</th>
<th>pH</th>
<th>Swell / Consolidation % Applied Load</th>
<th>Unconfined Compressive Strength (psf)</th>
<th>R-Value</th>
<th>AASHTO</th>
<th>USCS</th>
<th>Material Description</th>
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<td>3.0</td>
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<td>114</td>
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<td>49.0-49.5</td>
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<tr>
<td>P-1</td>
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<td>SPT</td>
<td>8.7</td>
<td>31</td>
<td>41</td>
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<td>24</td>
<td>16</td>
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<td></td>
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<td></td>
<td></td>
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<td>A-2-4 (0) SC SAND, clayey with gravel</td>
<td></td>
<td></td>
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<tr>
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<td>2.0</td>
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<td>P-2</td>
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<td>10</td>
<td>89</td>
<td>39</td>
<td>16</td>
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<td>30,477</td>
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<tr>
<td>P-2A</td>
<td>0.5-1.0</td>
<td>Bulk</td>
<td>13.6*</td>
<td>119**</td>
<td>4</td>
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<td>15</td>
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<td>418,522</td>
<td>CLAY, with sand</td>
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</tr>
<tr>
<td>P-3</td>
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<td>WEATHERED SHALE</td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

**MC - Indicates Modified California sampler**  
**SPT - Indicates Split Spoon sampler**  
**Bulk - Indicates auger cuttings**  
**Core - Indicates HQ3 core samples**  

* Optimum Moisture Content (%)  
** Maximum Dry Density (pcf)
Sample Description: SAND, clayey with gravel (SC)

Gravel (%): 31  LL  24  Project Name: MESA-16-Q.5 Bridge Replacement
Sand (%): 41  PL  16  Test Hole: P-1
Fines (%): 28  PI  8  Sample Depth (ft.): 0.7

Yeh & Associates, Inc.
Geotechnical Engineering Consultants

SIEVE ANALYSIS

Drawn By: JM  Checked By: SWR  Date: 12/18/18
Project No.: 218-192  Figure No.: C-4
Sieve Analysis

<table>
<thead>
<tr>
<th>Sieve Opening in Inches</th>
<th>U.S. Standard Sieves</th>
<th>Hydrometer Analysis</th>
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<td>6&quot;</td>
<td></td>
</tr>
<tr>
<td>3&quot;</td>
<td>3/4&quot;</td>
<td></td>
</tr>
<tr>
<td>2&quot;</td>
<td>3/8&quot;</td>
<td></td>
</tr>
<tr>
<td>1 1/2&quot;</td>
<td>1/2&quot;</td>
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</tr>
<tr>
<td>1&quot;</td>
<td>3/8&quot;</td>
<td></td>
</tr>
<tr>
<td>¾&quot;</td>
<td>3/4&quot;</td>
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</tr>
<tr>
<td>½&quot;</td>
<td>2&quot;</td>
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</tr>
<tr>
<td>⅜&quot;</td>
<td>1½&quot;</td>
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</tr>
<tr>
<td>#4</td>
<td>#10</td>
<td></td>
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<td>#40</td>
<td>#200</td>
<td></td>
</tr>
<tr>
<td>1&quot;</td>
<td>100</td>
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<td>¾&quot;</td>
<td>100</td>
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</tr>
<tr>
<td>½&quot;</td>
<td>100</td>
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<td>⅜&quot;</td>
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<tr>
<td>#200</td>
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</tbody>
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Gravel (%) | 1 | LL | 39 | Project Name: MESA-16-Q.5 Bridge Replacement
Sand (%) | 10 | PL | 16 | Test Hole: P-2
Fines (%) | 89 | PI | 23 | Sample Depth (ft.): 0.5 - 1.5 (Bulk)

Sample Description: CLAY (CL)

Yeh & Associates, Inc.
Geotechnical Engineering Consultants

SIEVE ANALYSIS

Drawn By: JM  Checked By: SWR  Date: 12/18/18  Project No.: 218-192
Figure No.: C-5
### Sieve Analysis

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<thead>
<tr>
<th>Particle Size (mm)</th>
<th>U.S. Standard Sieves</th>
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<td>12&quot;</td>
<td>6&quot;</td>
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<tr>
<td>100</td>
<td>70</td>
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</tbody>
</table>

**Gravel (%)**
- LL: 4%
- Project Name: MESA-16-Q.5 Bridge

**Sand (%)**
- LL: 21%
- Sample: P-2A

**Fines (%)**
- LL: 75%
- Sample Description: CLAY, with sand (CL)

**Sample Depth (ft):** 0.5' - 1.0'

---

**Hydrometer Analysis**

**Sample Description:** CLAY, with sand (CL)

**Project Details:**
- Project No.: 218-192
- Figure No.: B-6

---

**Yeh & Associates, Inc.**
Geotechnical Engineering Consultants

**Drawn By:** JM
**Checked By:** SWR
**Date:** 03/21/19
**Project No.:** 218-192
**Figure No.:** B-6
Compaction Test Procedure: AASHTO T180

Project No: 218-192  Method: A

Lab. Maximum Dry Density (MDD),pcf: 119.2

Lab. Optimum Moisture Content (OMC), %: 13.6

Sample Location / Station  Depth (ft.)  LL  PL  PI  -#200 (%)  Soil Description  Classification  Drawn by  Date  Checked by
Hand-Excavated Sample Near P-2  0.5-1.0  25  15  10  75  CLAY, with sand  A-4 (5) CL  MB  3/22/2019  MB

Laboratory Compaction (Proctor) Graph

Zero Air Void Curves - Curves of 100% Saturation for Sp.G. Equal to: 2.55, 2.60, 2.65, 2.70, 2.75, 2.80
<table>
<thead>
<tr>
<th>Job No: 218-192</th>
<th>Project Name: MESA-16-Q.5 Bridge Replacement</th>
<th>SWELL / CONSOLIDATION GRAPH</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number</td>
<td>Boring Number</td>
<td>Depth (ft)</td>
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<td>1</td>
<td>A-1</td>
<td>3.0</td>
</tr>
<tr>
<td>2</td>
<td>A-1</td>
<td>6.0</td>
</tr>
</tbody>
</table>

**Graph 1**

Consolidation(-)/Swell(+), %

Applied Normal Pressure, ksf

**Graph 2**

Consolidation(-)/Swell(+), %

Applied Normal Pressure, ksf

WATER ADDED

Consolidation(-)/Swell(+), %

WATER ADDED
Graph 1

Consolidation (-)/Swell (+), %

Applied Normal Pressure, ksf

Graph 2

Consolidation (-)/Swell (+), %

Applied Normal Pressure, ksf

<table>
<thead>
<tr>
<th>Graph Number</th>
<th>Boring Number</th>
<th>Depth (ft)</th>
<th>Natural Dry Density (pcf)</th>
<th>Moisture Content (%)</th>
<th>Swell (+)/ Consolidation (-) (%)</th>
<th>Soil Description</th>
<th>SWELL / CONSOLIDATION GRAPH</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>A-1</td>
<td>9.0</td>
<td>115</td>
<td>10.5</td>
<td>0.2</td>
<td>Weathered Shale</td>
<td>Drawn By: JRM</td>
</tr>
<tr>
<td>2</td>
<td>A-2</td>
<td>9.0</td>
<td>112</td>
<td>15.7</td>
<td>0.3</td>
<td>Weathered Shale</td>
<td>Checked By: SWR</td>
</tr>
</tbody>
</table>

Job No: 218-192  Project Name: MESA-16-Q.5 Bridge Replacement

Figure C-2

YEH & ASSOCIATES, INC.
Applied Normal Pressure, ksf

Graph 1

WATER ADDED

Consolidation(-)/Swell(+), %

Graph 2

Consolidation(-)/Swell(+), %

Applied Normal Pressure, ksf

<table>
<thead>
<tr>
<th>Graph Number</th>
<th>Boring Number</th>
<th>Depth (ft)</th>
<th>Natural Dry Density (pcf)</th>
<th>Moisture Content (%)</th>
<th>Swell(+) / Consolidation(-) (%)</th>
<th>Soil Description</th>
<th>Drawn By:</th>
<th>Checked By:</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>P-3</td>
<td>1.0</td>
<td>108</td>
<td>6.7</td>
<td>1.8</td>
<td>Weathered Shale</td>
<td>JRM</td>
<td>SWR</td>
</tr>
</tbody>
</table>

Job No: 218-192  Project Name: MESA-16-Q,5 Bridge Replacement

YEH & ASSOCIATES, INC.

Figure C-3
Test Hole A-1 Core Depth 25.5 to 35.0 ft
Test Hole A-1 Core Depth 35.0 to 38.0 ft
Test Hole A-2 Core Depth 12.0 to 21.5 ft
Test Hole A-2 Core Depth 21.5 to 31.0 ft
Test Hole A-2 Core Depth 31.0 to 41.0 ft
Test Hole A-2 Core Depth 41.0 to 51.0 ft
Appendix D

ESALs and TRAFFIC LOADING CALCULATIONS
Given: Traffic Counts from Mesa County for 2018

<table>
<thead>
<tr>
<th>Average Daily Traffic (ADT)</th>
<th>Flexible Pavement Factors</th>
</tr>
</thead>
<tbody>
<tr>
<td>2018 ADT</td>
<td># Lanes</td>
</tr>
<tr>
<td>244</td>
<td>2</td>
</tr>
<tr>
<td>20-Year Factor</td>
<td>Design Life (years)</td>
</tr>
<tr>
<td>20%</td>
<td>20</td>
</tr>
<tr>
<td>2038 ADT</td>
<td>Load Equivalencies</td>
</tr>
<tr>
<td>293</td>
<td>Passenger Vehicle</td>
</tr>
<tr>
<td>Average ADT</td>
<td>0.003</td>
</tr>
<tr>
<td>268</td>
<td>Single Axle</td>
</tr>
<tr>
<td></td>
<td>0.249</td>
</tr>
<tr>
<td></td>
<td>Truck Traffic</td>
</tr>
<tr>
<td></td>
<td>1.087</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Traffic Mix</th>
<th>Traffic Loading - Flexible</th>
</tr>
</thead>
<tbody>
<tr>
<td>% Passenger</td>
<td>EDLA</td>
</tr>
<tr>
<td>0.900</td>
<td>19</td>
</tr>
<tr>
<td>% Single Axle</td>
<td>ESAL</td>
</tr>
<tr>
<td>0.050</td>
<td>136,173</td>
</tr>
<tr>
<td>% Truck Traffic</td>
<td>Factored Loads</td>
</tr>
<tr>
<td>0.050</td>
<td>EDLA</td>
</tr>
<tr>
<td>Lane Factor (per direction)</td>
<td>11</td>
</tr>
<tr>
<td>0.6</td>
<td>ESAL</td>
</tr>
<tr>
<td></td>
<td>81,704</td>
</tr>
<tr>
<td></td>
<td>Use ESAL</td>
</tr>
<tr>
<td></td>
<td>100,000</td>
</tr>
</tbody>
</table>

For Flexible Pavement Design, use ESAL = 100,000
1993 AASHTO Pavement Design

DARWin Pavement Design and Analysis System

A Proprietary AASHTOWare
Computer Software Product
Yeh & Associates, Inc.

Flexible Structural Design Module

MESA-16-Q.5 Bridge Improvement
Mesa County, Colorado

Flexible Structural Design

18-kip ESALs Over Initial Performance Period 100,000
Initial Serviceability 4.5
Terminal Serviceability 2
Reliability Level 95 %
Overall Standard Deviation 0.49
Roadbed Soil Resilient Modulus 3,803 psi
Stage Construction 1

Calculated Design Structural Number 3.17 in

Specified Layer Design

<table>
<thead>
<tr>
<th>Layer</th>
<th>Material Description</th>
<th>Struct Coef. (Ai)</th>
<th>Drain Coef. (Mi)</th>
<th>Thickness (Di) (in)</th>
<th>Width (ft)</th>
<th>Calculated SN (in)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Hot Mix Asphalt</td>
<td>0.44</td>
<td>1</td>
<td>4.5</td>
<td>-</td>
<td>1.98</td>
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<tr>
<td>2</td>
<td>Class 6 ABC</td>
<td>0.12</td>
<td>1</td>
<td>10</td>
<td>-</td>
<td>1.20</td>
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<tr>
<td>Total</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>14.50</td>
<td>-</td>
<td>3.18</td>
</tr>
</tbody>
</table>
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<th>Thickness (Di)(in)</th>
<th>Width (ft)</th>
<th>Calculated SN (in)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Hot Mix Asphalt</td>
<td>0.44</td>
<td>1</td>
<td>5</td>
<td>-</td>
<td>2.20</td>
</tr>
<tr>
<td>2</td>
<td>Class 6 ABC</td>
<td>0.12</td>
<td>1</td>
<td>9</td>
<td>-</td>
<td>1.08</td>
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<tr>
<td>Total</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>14.00</td>
<td>-</td>
<td>3.28</td>
</tr>
</tbody>
</table>
1993 AASHTO Pavement Design

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Flexible Structural Design Module

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Stage Construction 1

Calculated Design Structural Number 3.17 in

**Specified Layer Design**

<table>
<thead>
<tr>
<th>Layer</th>
<th>Material Description</th>
<th>Struct Coef. (Ai)</th>
<th>Drain Coef. (Mi)</th>
<th>Thickness (Di,in)</th>
<th>Width (ft)</th>
<th>Calculated SN (in)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Hot Mix Asphalt</td>
<td>0.44</td>
<td>1</td>
<td>6</td>
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<tr>
<td>2</td>
<td>Class 6 ABC</td>
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<td>5</td>
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<td>0.60</td>
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<tr>
<td>Total</td>
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<td>-</td>
<td>-</td>
<td>11.00</td>
<td>-</td>
<td>3.24</td>
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</table>
## Asphalt Binder Selection Data

### Five Closest Weather Stations

<table>
<thead>
<tr>
<th>Weather Station</th>
<th>State/Province</th>
<th>Latitude</th>
<th>Longitude</th>
<th>Elevation, m</th>
</tr>
</thead>
<tbody>
<tr>
<td>FRUITA 1 w</td>
<td>CO</td>
<td>39.17</td>
<td>108.75</td>
<td>1268</td>
</tr>
</tbody>
</table>

### General

<table>
<thead>
<tr>
<th>Station ID</th>
<th>A=11 km</th>
<th>B=19 km</th>
<th>C=26 km</th>
<th>D=36 km</th>
<th>E=39 km</th>
</tr>
</thead>
<tbody>
<tr>
<td>CO3146</td>
<td>✓</td>
<td></td>
<td>✓</td>
<td></td>
<td>✓</td>
</tr>
</tbody>
</table>

### County/District

<table>
<thead>
<tr>
<th>Weather Station</th>
<th>Elevation, m</th>
<th>Latitude, Longitude</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mesa</td>
<td>1269</td>
<td>39.17,108.75</td>
</tr>
</tbody>
</table>

### Air Temperature

<table>
<thead>
<tr>
<th>High Temperature</th>
<th>Mean (Std. N)</th>
<th>Low Temperature</th>
<th>Mean (Std. N)</th>
<th>Low Temperature Drop</th>
<th>Mean (Std. N)</th>
<th>Degree-Days &gt; 10C</th>
<th>Mean (Std. N)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>36.4 (10.33)</td>
<td>-23 (60.34)</td>
<td>28 (23.34)</td>
<td>3379 (190.33)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### PG

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>59.5 -15.5</td>
<td>58.2 -11.7</td>
<td>59.5 -13.1</td>
<td>58.8 -12.3</td>
<td>60.3 -11.2</td>
</tr>
</tbody>
</table>

### State/Province

<table>
<thead>
<tr>
<th>Weather Station</th>
<th>State/Province</th>
<th>Latitude</th>
<th>Longitude</th>
<th>Elevation, m</th>
</tr>
</thead>
<tbody>
<tr>
<td>FRUITA 1 w</td>
<td>CO</td>
<td>39.17</td>
<td>108.75</td>
<td>1268</td>
</tr>
</tbody>
</table>

### Air Temperature

<table>
<thead>
<tr>
<th>High Air Temperature, Deg. C</th>
<th>Mean</th>
<th>Std Dev</th>
<th>Min</th>
<th>Max</th>
<th>Years</th>
</tr>
</thead>
<tbody>
<tr>
<td>36.4</td>
<td>34.3</td>
<td>38.5</td>
<td>33</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Pavement Temperature and PG

<table>
<thead>
<tr>
<th>Pavement Temperature, C</th>
<th>High</th>
<th>Low</th>
<th>High Rel</th>
<th>Low Rel</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>59.5</td>
<td>-15.5</td>
<td>50</td>
<td>50</td>
</tr>
</tbody>
</table>

### “Fruita 1 w” Weather Station
### Top Mat Recommended Binder – PG 64-16

<table>
<thead>
<tr>
<th>Parameter</th>
<th>A=11 km</th>
<th>B=19 km</th>
<th>C=26 km</th>
<th>D=36 km</th>
<th>E=38 km</th>
</tr>
</thead>
<tbody>
<tr>
<td>Station ID</td>
<td>CO3146</td>
<td>CO1772</td>
<td>CO3488</td>
<td>CO3489</td>
<td>CO6266</td>
</tr>
<tr>
<td>Elevation, m</td>
<td>4161</td>
<td>5369</td>
<td>4486</td>
<td>4422</td>
<td>4486</td>
</tr>
<tr>
<td>Degree-Days &gt;10 C</td>
<td>3379</td>
<td>3210</td>
<td>3372</td>
<td>3284</td>
<td>3483</td>
</tr>
<tr>
<td>Low Air Temperature, C</td>
<td>-23</td>
<td>-17.7</td>
<td>-19.7</td>
<td>-18.6</td>
<td>-17.1</td>
</tr>
<tr>
<td>Low Air Temp. Std Dev</td>
<td>6</td>
<td>3.9</td>
<td>4.9</td>
<td>4.6</td>
<td>4.7</td>
</tr>
</tbody>
</table>

**Input Data**
- Latitude, Degree: 39.26
- Yearly Degree-Days >10 Deg C: 3379

**Temperature Adjustments**
- Base HT PG: 64
- Desired Reliability, %: 50
- Depth of Layer, mm: 0

**Traffic Adjustments for HT**

<table>
<thead>
<tr>
<th>Traffic Speed</th>
<th>Traffic Loading</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fast</td>
<td>Slow</td>
</tr>
<tr>
<td>Up to 3 M. ESAL</td>
<td>0.0</td>
</tr>
<tr>
<td>3 to 10 M. ESAL</td>
<td>6.5</td>
</tr>
<tr>
<td>10 to 30 M. ESAL</td>
<td>11.3</td>
</tr>
<tr>
<td>Above 30 M. ESAL</td>
<td>13.4</td>
</tr>
</tbody>
</table>

**PG Temperature**

<table>
<thead>
<tr>
<th>PG Temp. at 50% Reliability</th>
<th>HIGH</th>
<th>LOW</th>
</tr>
</thead>
<tbody>
<tr>
<td>PG Temp. at Desired Reliability</td>
<td>89.8</td>
<td>-16.5</td>
</tr>
</tbody>
</table>

**Adjustments for Traffic**
- 0

**Adjusted for Depth**
- 0.0

**Selected PG Binder Grade**
- 64
- 16

---

### Lower Lift Recommended Binder – PG 64-28

<table>
<thead>
<tr>
<th>Parameter</th>
<th>A=11 km</th>
<th>B=19 km</th>
<th>C=26 km</th>
<th>D=36 km</th>
<th>E=38 km</th>
</tr>
</thead>
<tbody>
<tr>
<td>Station ID</td>
<td>CO3146</td>
<td>CO1772</td>
<td>CO3488</td>
<td>CO3489</td>
<td>CO6266</td>
</tr>
<tr>
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<td>4161</td>
<td>5369</td>
<td>4486</td>
<td>4422</td>
<td>4486</td>
</tr>
<tr>
<td>Degree-Days &gt;10 C</td>
<td>3379</td>
<td>3210</td>
<td>3372</td>
<td>3284</td>
<td>3483</td>
</tr>
<tr>
<td>Low Air Temperature, C</td>
<td>-23</td>
<td>-17.7</td>
<td>-19.7</td>
<td>-18.6</td>
<td>-17.1</td>
</tr>
<tr>
<td>Low Air Temp. Std Dev</td>
<td>8</td>
<td>3.9</td>
<td>4.9</td>
<td>4.6</td>
<td>4.7</td>
</tr>
</tbody>
</table>

**Input Data**
- Latitude, Degree: 39.26
- Yearly Degree-Days >10 Deg C: 3379

**Temperature Adjustments**
- Base HT PG: 64
- Desired Reliability, %: 90
- Depth of Layer, mm: 50

**Traffic Adjustments for HT**

<table>
<thead>
<tr>
<th>Traffic Speed</th>
<th>Traffic Loading</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fast</td>
<td>Slow</td>
</tr>
<tr>
<td>Up to 3 M. ESAL</td>
<td>0.0</td>
</tr>
<tr>
<td>3 to 10 M. ESAL</td>
<td>6.5</td>
</tr>
<tr>
<td>10 to 30 M. ESAL</td>
<td>11.3</td>
</tr>
<tr>
<td>Above 30 M. ESAL</td>
<td>13.4</td>
</tr>
</tbody>
</table>

**PG Temperature**

<table>
<thead>
<tr>
<th>PG Temp. at 50% Reliability</th>
<th>HIGH</th>
<th>LOW</th>
</tr>
</thead>
<tbody>
<tr>
<td>PG Temp. at Desired Reliability</td>
<td>59.5</td>
<td>-16.5</td>
</tr>
</tbody>
</table>

**Adjustments for Traffic**
- 2.6

**Adjusted for Depth**
- -4.9

**Selected PG Binder Grade**
- 64
- -28