

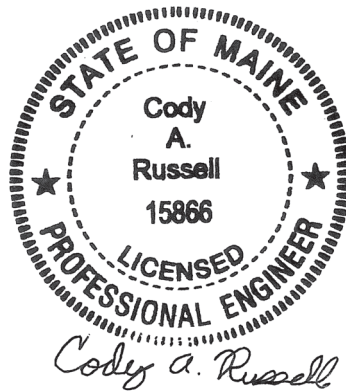
**MAINE DEPARTMENT OF TRANSPORTATION
HIGHWAY PROGRAM
GEOTECHNICAL SECTION
AUGUSTA, MAINE**

GEOTECHNICAL DESIGN REPORT

For the Construction of:

**TRIBUTARY TO PENOBSCOT BRIDGE
U.S. ROUTE 2
ORONO, MAINE**

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Penobscot County
WIN 20898.00

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Soils Report 2021-13
Bridge No. 6587

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1.0 INTRODUCTION

The purpose of this Geotechnical Design Report is to present subsurface information and make geotechnical recommendations for the replacement of an existing large culvert (#942495) on U.S. Route 2 in Orono, Maine. A subsurface investigation has been completed at the site to evaluate subsurface conditions and to develop geotechnical design and construction recommendations for the replacement structure. This report presents the subsurface information obtained during the subsurface investigation and soil laboratory testing programs and provides design and construction recommendations and geotechnical design parameters for the culvert replacement.

The existing structure consists of an approximately 50-inch span by 41-inch rise by 99-foot long concrete box culvert. The concrete at both the inlet and the outlet of the existing structure has disintegrated leaving exposed reinforcing steel extending beyond the culvert ends. U.S. Route 2 is a Highway Corridor Priority 3 road.

The proposed replacement structure will be a 12-foot span by 8-foot rise by 160-foot long precast concrete box culvert. To facilitate fish passage, Habitat Connectivity Design elements will be used inside the precast concrete box culvert as shown on the Special Details Sheet in the Plans. The invert of the proposed culvert is approximately 25.0 feet below the existing road grade at the roadway centerline. The roadway embankment slopes at the proposed culvert inlet and outlet shall be no steeper than 2H:1V to protect against erosion.

2.0 GEOLOGIC SETTING

The existing culvert carries an unnamed tributary to the Penobscot River under U.S. Route 2 in Orono and is located approximately 0.66 miles north of the Veazie town line as shown on Sheet 1 – Location Map.

According to the Maine Geological Survey (MGS) map titled Surficial Geology Veazie Quadrangle, Maine, Open File 11-32 (2011) the surficial soils at the site consist of Presumpscot Formation. Presumpscot Formation consists of glaciomarine silt, clay, and sand.

According to the map titled Bedrock Geologic Map of Maine (1985) published by the MGS, the bedrock in the vicinity of the site consists of calcareous sandstone and interbedded sandstone and impure limestone of the Vassalboro Formation.

3.0 SUBSURFACE INVESTIGATION

Two (2) borings (HB-ORCU-101 and HB-ORCU-102) were drilled in the roadway on opposite, diagonal corners of the existing structure on March 23, 2017 by the New England Boring Contractors (NEBC) drill crew using a trailer mounted drill rig. Exploration locations are shown on Sheet 2 – Boring Location Plan & Interpretive Subsurface Profile. Details and sampling methods used, field data obtained, and soil and groundwater conditions encountered are presented on the Boring Logs in Appendix A.

Boring HB-ORCU-101 was drilled using solid stem auger drilling techniques. Boring HB-ORCU-102 was drilled using hollow solid stem auger drilling techniques. One soil sample was obtained from the auger cuttings of boring HB-ORCU-101. Soil samples were obtained in boring HB-ORCU-102 at 5-foot intervals using Standard Penetration Test (SPT) methods. The NEBC drill rig is equipped with a manually operated rope and cathead hammer to drive the split spoon.

The MaineDOT Geotechnical Team member selected the boring locations, drilling methods, designated type and depth of sampling, reviewed field logs for accuracy and identified field and laboratory testing requirements. A NorthEast Transportation Training and Certification (NETTCP) certified Subsurface Investigator logged the subsurface conditions encountered in the borings. The borings were located in the field by taping to surveyed site features after completion of the drilling program.

4.0 LABORATORY TESTING

A laboratory testing program was conducted to assist in soil classification, evaluation of engineering properties of the soils and geologic assessment of the project site. Laboratory testing consisted of five (5) standard grain size analysis with natural water content and four (4) standard grain size analyses with hydrometer and natural water content. The results of the laboratory testing program are discussed in the following section and are included in Appendix B – Laboratory Test Results. Laboratory test information is also shown on the Boring Logs in Appendix A.

5.0 SUBSURFACE CONDITIONS

Subsurface conditions encountered in the test borings generally consisted fill sand, gravelly sand, and sandy gravel underlain by native silt and sandy silt. An interpretive subsurface profile depicting the generalized soil stratigraphy at the boring location is shown on Sheet 2 – Boring Location Plan & Interpretive Subsurface Profile.

Boring HB-ORCU-101 was drilled to a depth of approximately 30.0 feet below ground surface (bgs) and did not encounter a refusal surface. Boring HB-ORCU-102 was drilled to a depth of approximately 32.0 feet bgs and did not encounter a refusal surface.

The table below summarizes the field and laboratory information obtained in boring HB-ORCU-102:

Approx. Depth BGS ¹ (feet)	Soil Description	AASHTO ² Classification	USCS ³	WC% ⁴
0.0 – 0.7	Pavement	--	--	--
0.7 – 17.0	Fill – Brown and grey, damp to moist, fine to coarse sandy gravel, gravelly fine to coarse sand and fine to coarse sand, trace to some	A-1-a or A-1-b	GW-GM, SM or GM	2.6 to 7.6

	silt, occasional cobble.			
17.0 – 32.0	Brown, grey, and olive brown, wet, silt, some fine to coarse sand, trace to some gravel, Grey, wet, fine to coarse sandy silt, trace clay, trace gravel, trace to some organics.	A-4	SM or CL	9.3 to 45.3

¹BGS = below ground surface

²AASHTO = American Association of State Highway and Transportation Officials

³USCS = Unified Soil Classification System

⁴WC% = Water content in percent

Four (4) N-values obtained in the fill ranged from 24 to 43 blows per foot (bpf) indicating that the fill is medium dense to dense in consistency. Three (3) N-values obtained in the silt and sandy silt ranged from 6 to 19 bpf indicating that the silt is medium stiff to very stiff in consistency.

One soil sample was obtained in boring HB-ORCU-101 from the auger cutting between approximately 16.0 to 22.0 feet bgs. The lab testing results of the sample were similar to the silt samples obtained in HB-ORCU-102 described in the table above.

Groundwater level was not recorded in the borings. Groundwater levels can be expected to fluctuate subject to seasonal variations, local soil conditions, topography, precipitation, and construction activity.

6.0 GEOTECHNICAL DESIGN AND CONSTRUCTION RECOMMENDATIONS

The proposed replacement structure will consist of a 12-foot span by 8-foot rise by 160-foot long precast concrete box culvert. The proposed structure inlet and outlet slopes shall be rippapped with slopes no steeper than 2H:1V to protect against erosion. The following sections discuss geotechnical recommendations for the design and construction of the proposed culvert.

6.1 Precast Concrete Box Culvert Design and Construction

The proposed replacement structure will consist of a 12-foot span by 8-foot rise by 160-foot long precast concrete box culvert. The proposed box culvert shall be designed and constructed in accordance with MaineDOT Standard Specification 534.

The elevation of the proposed box culvert is set at approximately 101.7 feet at the inlet and 99.9 feet at the outlet. To facilitate fish passage, Habitat Connectivity Design elements will be used inside the precast concrete box culvert as shown on the Special Details Sheet in the Plans.

The full nature of the culvert bearing surface will not become evident until the culvert excavation is made. Any cobbles or boulders in excess of 6 inches encountered at the bedding elevation shall be removed and replaced with compacted Granular Borrow Material for Underwater Backfill or Crushed Stone ¾-Inch. Any disturbed soils at the bedding elevation resulting from excavation activities should be removed by hand prior to placement of the bedding material. The prepared subgrade shall be proofrolled using a static roller to visually confirm the prepared subgrade is firm

and stable. The exposed subgrade shall be free of ponded water so that bedding material placement and compaction can be completed in the dry.

The proposed structure shall be bedded on a 1-foot thick layer of Granular Borrow, Material for Underwater Backfill meeting the requirements of MaineDOT Standard Specification 703.19. The soil envelope and backfill shall consist of Standard Specification 703.19 - Granular Borrow with a maximum particle size of 4 inches. The Granular Borrow bedding and backfill material shall be placed in lifts of 6 to 8 inches loose measure and compacted to the manufacturer’s specifications or, in the absence of manufacturer’s specifications, the bedding and backfill soil shall be compacted to at least 92 percent of the AASHTO T-180 maximum dry density.

6.2 Settlement

No settlement issues are anticipated at the site. The proposed precast concrete box culvert is larger than the existing culvert and will result in a net unloading of the site soils at the structure location. Placement of fill soils at the location of the existing structure is not anticipated to exceed the past loading condition of the site soils. Any settlement due to elastic compression of the subgrade soils and bedding material will be immediate and negligible.

6.3 Bearing Resistance

The factored bearing resistances for the precast concrete box culvert bearing on compacted granular bedding material placed on native soils at the service and strength limit states are presented in the table below. Supporting calculations in accordance with AASHTO LRFD Bridge Design Specifications 9th Edition 2020 (LRFD) are provided in Appendix C – Calculations.

Limit State	Resistance Factor ϕ_b	AASHTO LRFD Reference	Factored Bearing Resistance (ksf)
Service	1.0	Article 10.5.5.1	4.0
Strength	0.45	Table 10.5.5.2.2-1	8.5

6.4 Modulus of Subgrade Reaction

A modulus of subgrade reaction (k_s) equal to 50 pounds per cubic inch shall be used for the structural design of the box culvert’s base slab. Calculations are included in Appendix C – Calculations.

6.5 Scour and Riprap

Both the inlet and outlet of the precast concrete box culvert shall be protected against scour with riprap conforming to MaineDOT Standard Specification Section 703.26 Plain and Hand Laid Riprap. Slopes shall be no steeper than 2H:1V. No specific scour protection recommendations are needed other than armoring with riprap. The riprap on the slopes shall be underlain by a non-woven, Class 1 Erosion Control Geotextile meeting the requirements of MaineDOT Standard

Specification 722.03 that is underlain by a 1-foot layer of protective aggregate cushion consisting of Granular Borrow Material for Underwater Backfill (703.19). The toe of the riprap sections shall be keyed into the existing soils 1 foot below the streambed elevation.

6.6 Seismic Design Considerations

In conformance with LRFD Article 3.10.1, seismic analysis is not required for buried structures, except where they cross active faults. There are no known active faults in Maine; therefore, seismic analysis is not required.

6.7 Construction Considerations

Construction activities may include construction of cofferdams and earth support systems to control stream flow during construction. Construction activities will also include common earth excavation. Construction of the proposed precast concrete box culvert will require deep soil excavation. Earth support systems shall be implemented if laying back slopes is not feasible. It is likely that the use of complex (four-sided) braced excavations with dewatering will be necessary due to the depth of the excavation. If this is the case, adequate embedment into native silts will be necessary to allow for the excavation and maintenance of a stable excavation bottom. All earth support systems shall be designed by a Professional Engineer licensed in the State of Maine. Regardless of the method of excavation, all excavations and earth support systems shall meet all applicable OSHA regulations.

The Contractor shall control groundwater and surface water infiltration using temporary ditches, sumps, granular drainage blankets, stone ditch protection or hand-laid riprap with geotextile underlayment to divert groundwater and surface water as needed to maintain a stable excavation and allow work in the dry.

Using the excavated native soils as backfill around the culvert shall not be permitted. The native soils may only be used as common borrow in accordance with MaineDOT Standard Specifications 203 and 703.

The Contractor will have to excavate the existing subbase and subgrade fill soils in the vicinity of the culvert. These materials should not be used to re-base the roadway. Excavated subbase sand and gravel may be used as fill below roadway subgrade level in fill areas provided all other requirements of MaineDOT Standard Specifications 203 and 703 are met.

7.0 CLOSURE

This report has been prepared for the use of the MaineDOT Highway Program for specific application to the proposed replacement of an existing large culvert (#942495) under U.S. Route 2 in Orono, Maine in accordance with generally accepted geotechnical and foundation engineering practices. No other intended use or warranty is expressed or implied.

In the event that any changes in the nature, design, or location of the proposed project are planned, this report should be reviewed by a geotechnical engineer to assess the appropriateness of the

conclusions and recommendations and to modify the recommendations as appropriate to reflect the changes in design. These analyses and recommendations are based in part upon a limited subsurface investigation at discrete exploratory location completed at the site. If variations from the conditions encountered during the investigation appear evident during construction, it may also become necessary to re-evaluate the recommendations made in this report.

It is recommended that a geotechnical engineer be provided the opportunity for a review of the design and specifications in order that the earthwork and foundation recommendations and construction considerations presented in this report are properly interpreted and implemented in the design and specifications.

Sheets



ORONO, MAINE



The Maine Department of Transportation provides this publication for information only. Reliance upon this information is at user risk. It is subject to revision and may be incomplete depending upon changing conditions. The Department assumes no liability if injuries or damages result from this information. This map is not intended to support emergency dispatch.

0.15 Miles
1 inch = 0.21 miles

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SHEET NUMBER

1

OF 2

ORONO
US ROUTE 2

LOCATION MAP

STATE OF MAINE
DEPARTMENT OF TRANSPORTATION

STP-2089(800)

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HIGHWAY PLANS

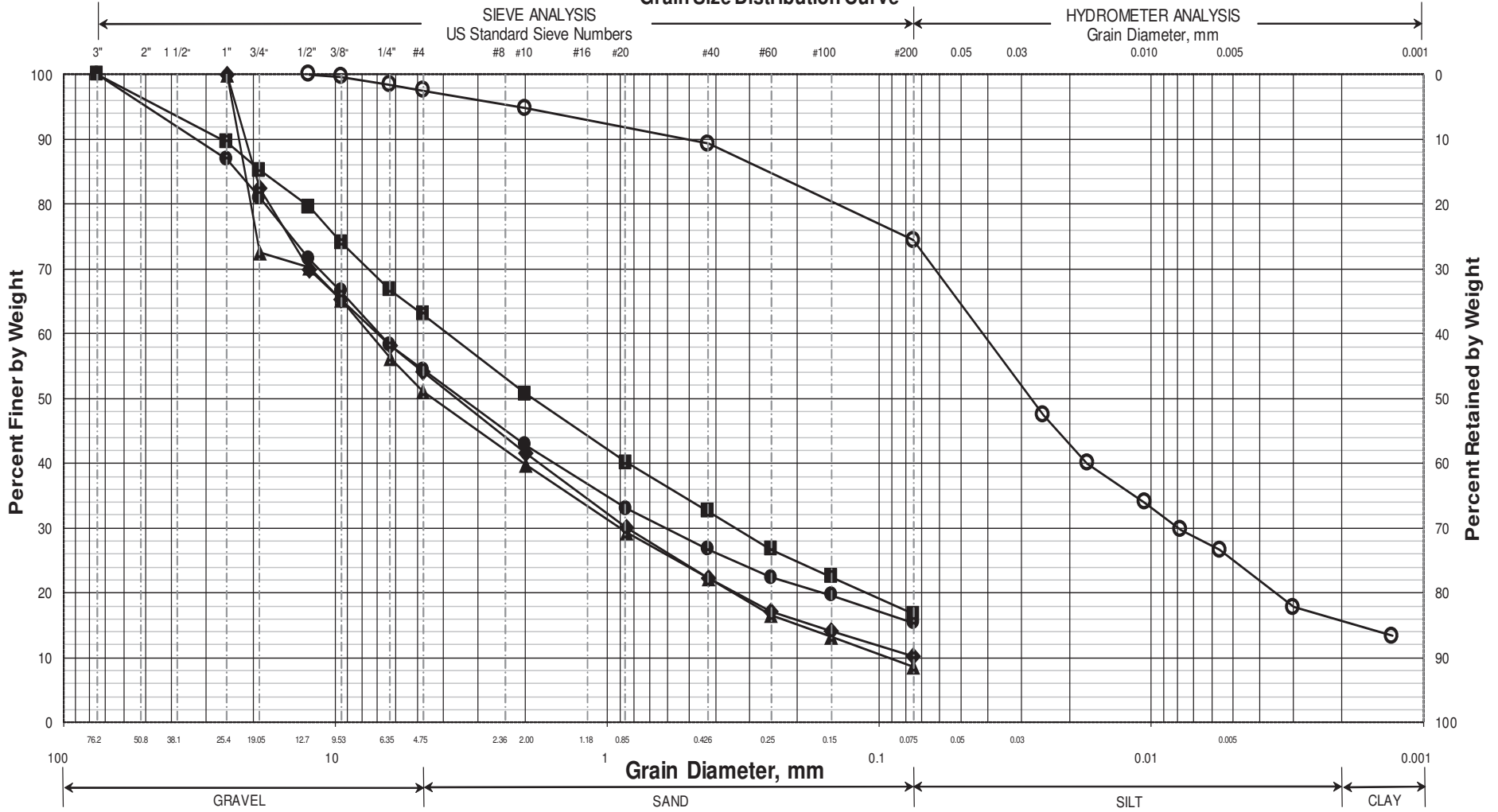
Appendix A

Boring Logs

Appendix B

Laboratory Test Results

Maine Department of Transportation Grain Size Distribution Curve

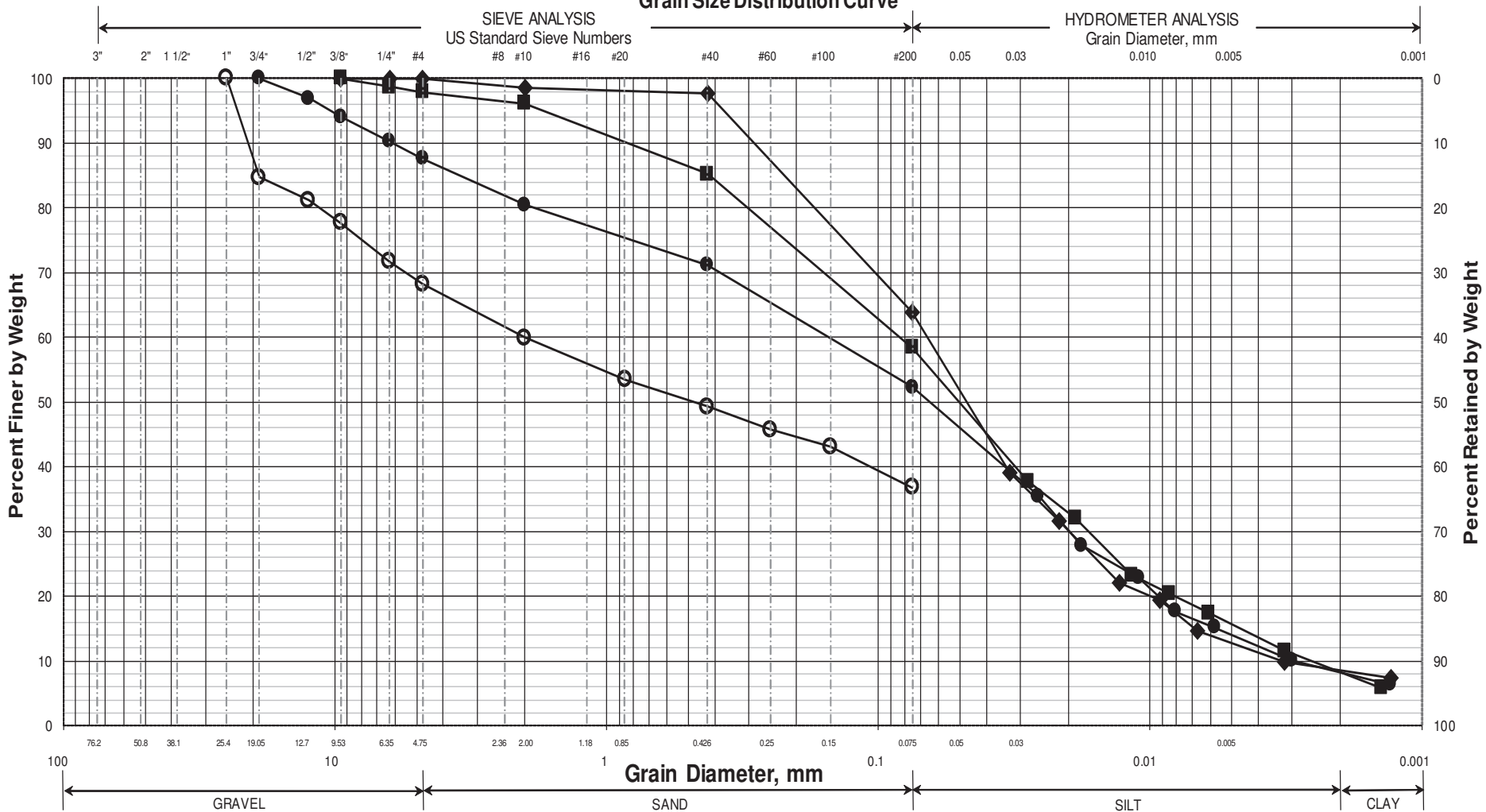


UNIFIED CLASSIFICATION

	Boring/Sample No.	Station	Offset, ft	Depth, ft	Description	WC, %	LL	PL	PI
○	HB-ORCU-101/S1	5+21.3	6.5 RT	16.0-20.0	SILT, some sand, little clay, trace gravel.	17.2			
◆	HB-ORCU-102/1D	5+50.4	7.4 LT	2.0-4.0	Sandy GRAVEL, trace silt.	2.6			
■	HB-ORCU-102/2D	5+50.4	7.4 LT	5.0-7.0	Gravelly SAND, little silt.	3.7			
●	HB-ORCU-102/3D	5+50.4	7.4 LT	10.0-12.0	Sandy GRAVEL, little silt.	7.6			
▲	HB-ORCU-102/4D	5+50.4	7.4 LT	15.0-17.0	Sandy GRAVEL, trace silt.	2.3			
X									

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Orono
Reported by/Date
WHITE, TERRY A 10/30/2020

Maine Department of Transportation Grain Size Distribution Curve



UNIFIED CLASSIFICATION

	Boring/Sample No.	Station	Offset, ft	Depth, ft	Description	WC, %	LL	PL	PI
○	HB-ORCU-102/5D	5+50.4	7.4 LT	20.0-22.0	SILT, some gravel, some sand.	12.5			
◆	HB-ORCU-102/6D	5+50.4	7.4 LT	25.0-26.2	SILT, some sand, trace clay, trace gravel.	21.6			
■	HB-ORCU-102/6DA	5+50.4	7.4 LT	26.2-27.0	Sandy SILT, trace clay, trace gravel.	45.3			
●	HB-ORCU-102/7D	5+50.4	7.4 LT	30.0-32.0	SILT, some sand, little gravel, trace clay.	9.3			
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Appendix C

Calculations

Bearing Resistance - Existing Soils:

Part 1 - Service Limit State

Nominal and factored Bearing Resistance - Box Culvert on Silt

Presumptive Bearing Resistance for Service Limit State ONLY

Reference: AASHTO LRFD Bridge Design Specifications 9th Edition 2020
Table C10.6.2.6.1-1 Presumptive Bearing Resistances for Spread Footings at the
Service Limit State Modified after US Department of Navy (1982)

Type of Bearing Material: Silt (CL)

Based on N-values, soils are medium stiff to very stiff near the bearing elevation

Density In Place: Stiff

Bearing Resistance: Ordinary Range (ksf) 2 to 6

Recommended Value of Use:

$$q_{nom} := 4 \cdot ksf$$

Resistance factor at the **service limit state** = 1.0 (LRFD Article 10.5.5.1)

$$\phi_{service_bc} := 1.0$$

$$q_{factored_service_bc} := q_{nom} \cdot \phi_{service_bc}$$

$$q_{factored_service_bc} = 4 \cdot ksf$$

Note: This bearing resistance is settlement limited (1 inch) and applies only at the service limit state.

Part 2 - Strength Limit State

Nominal and factored Bearing Resistance - Box Culvert on Silt

Reference: AASHTO LRFD Bridge Design Specifications 9th Edition 2020 - Article 10.6.3.1

Assumptions:

1. The box will be founded at ~ Elev 99.8 feet

Bottom of Construction will be 2 feet below box invert

$$D_{footing} := 2.0 \cdot ft$$

2. Assumed parameters for fill soils:

Saturated unit weight: $\gamma_s := 125 \cdot pcf$

Internal friction angle: $\phi_{ns} := 32 \cdot deg$

Undrained shear strength: $c_{ns} := 0 \cdot psf$

3. Box Culvert parameters

Width of box culvert, B $B_{box} := 12 \cdot ft$

Length of box culvert, L $L_{box} := 160 \cdot ft$

Nominal Bearing Resistance per LRFD Equation 10.6.3.1.2a-1

$$q_n = cN_{cm} + \gamma D_f N_{qm} C_{wq} + 0.5\gamma B N_{\gamma m} C_{w\gamma}$$

Bearing Capacity Factors - LRFD Table 10.6.3.1.2a-1

For $\phi=32$ deg $N_c := 35.5$ $N_q := 23.2$ $N_\gamma := 30.2$

Shape Correction Factors LRFD Table 10.6.3.1.2a-3

for $\phi=32$ degrees

$$s_c := 1 + \left(\frac{B_{\text{box}}}{L_{\text{box}}} \right) \left(\frac{N_q}{N_c} \right) \quad s_c = 1.05$$

$$s_\gamma := 1 - 0.4 \left(\frac{B_{\text{box}}}{L_{\text{box}}} \right) \quad s_\gamma = 0.97$$

$$s_q := 1 + \left(\frac{B_{\text{box}}}{L_{\text{box}}} \cdot \tan(\phi_{ns}) \right) \quad s_q = 1.05$$

Load Inclination Factors:

Assume all are 1.0 (LRFD Article C10.6.3.1.2a)

$i_c := 1.0$ $i_q := 1.0$ $i_\gamma := 1.0$

Depth Correction Factor

$$d_q := 1 + 2 \cdot \tan(\phi_{ns}) \cdot (1 - \sin(\phi_{ns}))^2 \cdot \tan\left(\frac{D_{\text{footing}}}{B_{\text{box}}}\right)^{-1} \quad d_q = 2.6416$$

LRFD Eq. 10.6.3.1.2a-10

$N_{cm} := N_c \cdot s_c \cdot i_c$ $N_{cm} = 37.24$ LRFD Eq. 10.6.3.1.2a-2

$N_{qm} := N_q \cdot s_q \cdot d_q \cdot i_q$ $N_{qm} = 64.16$ LRFD Eq. 10.6.3.1.2a-3

$N_{\gamma m} := N_\gamma \cdot s_\gamma \cdot i_\gamma$ $N_{\gamma m} = 29.29$ LRFD Eq. 10.6.3.1.2a-4

Coefficients for Groundwater Depths LRFD Table 10.6.3.1.2a-2

Depth the water table: $D_w := 0 \cdot \text{ft}$ $C_{wq} := 0.5$ $C_{w\gamma} := 0.5$

$$q_{\text{nominal}} := c_{ns} \cdot N_{cm} + \gamma_s \cdot D_{\text{footing}} \cdot N_{qm} \cdot C_{wq} + 0.5(\gamma_s) B_{\text{box}} \cdot N_{\gamma m} \cdot C_{w\gamma}$$

$q_{\text{nominal}} = 19 \cdot \text{ksf}$

Factored Bearing Resistance for Strength Limit State

Resistance Factor: $\phi_b := 0.45$ LRFD Table 10.5.5.2.2-1

$q_{\text{factored}} := q_{\text{nominal}} \cdot \phi_b$

$q_{\text{factored}} = 8.6 \cdot \text{ksf}$

Recommend a limiting factored bearing resistance of 8.5 ksf for the Strength Limit State.

Modulus of Subgrade Reaction:

Reference: Foundation Analysis and Design 5th Edition JE Bowles Section 9-6

Width of box culvert, B $B_{\text{box}} = 12 \text{ ft}$
 Length of box culvert, L $L_{\text{box}} = 160 \text{ ft}$
 Thickness of box culvert, t $t_{\text{box}} := 12 \cdot \text{in}$ assumed
 Depth of box, D $D_{\text{box}} := 26.5 \cdot \text{ft}$
 Bearing Resistance: $q_{\text{factored_service_bc}} = 4 \cdot \text{ksf}$ Calculated above
 Modulus of Elasticity: Site soils at bearing elevation are Silt. Use values for Silt.
 From Bowles Table 2-8 Modulus E_s for Silt, dense ranges from 40 - 420 ksf

Use Modulus of Elasticity, E_s $E_s := 400 \cdot \text{ksf}$
 Poisson's Ratio: Site conditions at bearing elevation are Silt.
 From Bowles Table 2-7 Poisson's Ratio μ for Silt ranges from 0.3 - 0.35

Use Poisson's Ratio, μ $\mu := 0.35$

$$E_{\text{prime_s}} := \frac{1 - \mu^2}{E_s} \quad E_{\text{prime_s}} = 0.002194 \cdot \frac{\text{ft}^2}{\text{kip}}$$

Analyze corner:

Take H as 5*B as recommended in Bowles Chapter 5

$$H_{\text{inf}} := \frac{5 \cdot B_{\text{box}}}{B_{\text{box}}} \quad H_{\text{inf}} = 5 \quad \text{N in Table 5-2} \quad \text{From Table 5-2 for N=5 and M=13.3333}$$

$$\frac{L_{\text{box}}}{B_{\text{box}}} = 13.3333 \quad \text{M in Table 5-2} \quad I_1 := 0.531$$

$$I_2 := 0.143 \quad \text{by interpolation}$$

Determine Steinbrenner influence factor - Bowles Section 5-6:

$$I_s := I_1 + \left[\frac{1 - (2 \cdot \mu)}{1 - \mu} \right] \cdot I_2 \quad I_s = 0.597$$

Determine Influence factor for footing depth - Bowles Figure 5-7

Depth ratio: $\frac{D_{\text{box}}}{B_{\text{box}}} = 2.2083$ $\frac{L_{\text{box}}}{B_{\text{box}}} = 13.3333$ $\mu = 0.35$ $I_F := 0.70$

Calculate modulus of subgrade reaction - Bowles Eq. 9-7

$$k_s := \frac{1}{B_{\text{box}} \cdot E_{\text{prime_s}} \cdot I_s \cdot I_F} \quad \text{Bowles Eq. 9-7}$$

$$k_s = 53 \cdot \text{pci}$$

Recommend Modulus of Subgrade Reaction of 50 pci