MaineDOT TEDOCS No. 1096575

MaineDOT

State of Maine
Bridge Program - Geotechnical
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Soils Report 2010-28
Addendum #1

To:	Kris Constanzer, SEA/Kleinfelder
cc:	Nate Benoit, PE; TEDOCS
Author:	Kate Maguire, PE
Subject:	Replacement of Little Bridge Soils Report No. 2010-28 Updated Structure Type
Doc. Type:	24
Date:	January 25, 2011
Bridge No.:	3987
Route:	East Bridge Street
PIN:	16761.00
Town:	Westbrook

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The following changes are made to the Geotechnical Design Report for the Replacement of Little Bridge over Mill Brook Westbrook, Maine, Soils Report No. 2010-28:

At the time the original soils report was published (October 26, 2010) it was the intent of the MaineDOT Bridge Program to replace Little Bridge with a composite tubular arch bridge structure. During final design, the structural designer (SEA/Kleinfelder) made the decision to use a single concrete box culvert. This change was approved by the MaineDOT Bridge Program.

The purpose of this addendum is to provide geotechnical design recommendations for the single concrete box culvert founded on native soils. Precast Concrete Modular Gravity (PCMG) Block walls are planned for the culvert wingwalls.

The current proposed replacement structure consists of a single precast, 20 foot by 12 foot, concrete box culvert skewed at approximately 15 degrees. The bottom elevation for box culvert will be approximately elevation 12.0 feet. The box culvert will be embedded 2 feet below the streambed. The proposed box culvert will have inlet and outlet toe walls with PCMG wingwalls on all four corners. The overall length of the culvert will be approximately 50 feet. The existing roadway profile will be maintained in the replacement structure. Staged construction will be utilized in the replacement of the structure.

Precast Concrete Box Culvert Design and Construction - Precast concrete box culverts are typically detailed on the contract plans with only the basic layout and required hydraulic opening so that the Contractor may choose the appropriate structure. The Manufacturer is responsible for the design of the structure including determination of

the wall thickness, haunch thickness and reinforcement in accordance with Special Provision 534 Precast Concrete Arches, Box Culverts, which is attached to this addendum. The loading specified for the structure should be Modified HL-93 Strength 1, in which the HS-20 design truck wheel loads are increased by a factor of 1.25. The designer should use Soil Type 4 as presented in the Maine DOT Bridge Design Guide (BDG) Section 3.6 to design earth loads from the soil envelope. The backfill properties are as follows: ϕ = 32 degrees, γ = 125 pcf.

The precast concrete box shall include accommodations for toe walls at both the inlet and outlet ends to prevent undermining per MaineDOT BDG Section 8.3.1. The cutoff walls should extend below the maximum depth of scour.

The precast concrete box culvert will be supplier-designed in accordance with AASHTO LRFD Bridge Design Specifications 5th Edition 2010 (LRFD) specifications. The precast concrete box culvert shall be designed for all relevant strength and service limit states and load combinations specified in LRFD Article 3.4.1 and LRFD Section 12. The precast concrete box culvert shall be constructed in conformance with MaineDOT BDG Section 8 and Special Provision 534. The soil envelop and backfill shall consist of Standard Specification 703.19 - Granular Borrow Material for Underwater Backfill with a maximum particle size of 4 inches. A bedding layer of 12 inches is recommended below the precast concrete box culverts. Bedding and backfill shall be placed in lifts of 6 to 8 inches loose lift measure and compacted to the Manufacturer's specifications. Alternatively, crushed stone can be used as the bedding layer. The crushed stone bedding layer should be placed in 12 inch maximum thick lifts and compacted with a minimum of four passes of a large walk behind compactor. In no case shall the backfill soil be compacted less than 92 percent of the AASHTO T-180 maximum dry density.

Precast Concrete Box Culvert Bearing Resistance - The factored bearing resistance for at the strength limit state for the box culvert on compacted fill shall not exceed 5 ksf, however, the service limit state bearing resistance will govern. A factored bearing resistance of 3 ksf shall be used to control settlement when analyzing the service limit state as allowed in LRFD C10.6.2.6.1. In no instance shall the bearing stress exceed the nominal resistance of the structural concrete which may be taken as $0.3f'_c$. See Calculations for supporting documentation.

Precast Concrete Box Culvert Headwall Design - Concrete headwalls should be included in the culvert design to retain riprap slopes and prevent riprap from dropping or eroding into the waterway. A nominal 1 foot by 1 foot concrete headwall is recommended.

Larger precast or cast-in-place concrete box culvert headwalls are essentially retaining walls and shall be designed for all relevant strength and service limit states and load combinations specified in LRFD Articles 3.4.1, 11.5.5 and 11.6. The headwalls shall be designed to resist and/or absorb lateral earth loads, vehicular loads, creep, and temperature and shrinkage deformations of the concrete box culvert. The headwalls shall

be designed considering a live load surcharge equal to a uniform horizontal earth pressure due to an equivalent height of soil (h_{eq}) taken from Table 1 below:

Wall Height (feet)	h_{eq} (feet)	
	Distance from wall pressure surface to edge of traffic = 0 feet	Distance from wall pressure surface to edge of traffic ≥ 1 foot
5	5.0	2.0
10	3.5	2.0
≥20	2.0	2.0

Table 1 – Equivalent Height of Soil for Vehicular Loading on Retaining Walls

Culvert headwall sections that are fixed to the box culvert to resist movement should be designed using an at-rest earth pressure coefficient, K_o, of 0.5. Headwall sections that are independent of the box culvert should be designed using the Rankine active earth pressure coefficient, K_a, of 0.31 assuming a level back slope. The active earth pressure coefficient may change if the back slope conditions are different. See Calculations for supporting documentation.

Precast Concrete Modular Gravity (PCMG) Block Wingwalls - Precast Concrete Modular Gravity (PCMG) walls will be constructed on all four corners of the culvert as wingwalls. These walls shall be designed by a Professional Engineer subcontracted by the Contractor as a design-build item. The walls shall be designed in accordance with LRFD and Special Provision 635 which is included at the end of this addendum.

The PCMG wall designs shall consider a live load surcharge estimated as a uniform horizontal earth pressure due to an equivalent height of soil (h_{eq}) taken from Table 2 below:

Wall Height (feet)	h_{eq} (feet)	
	Distance from wall backface to edge of traffic = 0 feet	Distance from wall backface to edge of traffic ≥ 1 foot
5	5.0	2.0
10	3.5	2.0
≥20	2.0	2.0

Table 2 – Equivalent Height of Soil for Vehicular Loading on Retaining Walls

Bearing resistance for PCMG walls founded on a leveling slab on native soils shall be investigated at the strength limit state using factored loads and a factored bearing resistance of 3 ksf for walls less than 10 feet wide and 4 ksf for walls greater than 12 feet wide and less than 15 feet wide. The bearing resistance factor, ϕ_b, for footings on soil is 0.45. Based on presumptive bearing resistance values a factored bearing resistance of 3 ksf may be used to control settlement when analyzing the service limit state and for preliminary footing sizing assuming a resistance factor of 1.0.

The bearing resistance for PCMG bottom unit of the PCMG wall shall be checked for the extreme limit state with a resistance factor of 1.0. The PCMG units shall be designed so that the nominal bearing resistance after the design scour event provides adequate resistance to support the unfactored strength limit state loads with a resistance factor of 1.0. The overall stability of the wall system should be investigated at the Service I Load Combination with a resistance factor ϕ, of 0.65.

The designer shall apply a sliding resistance factor φ_τ of 0.90 to the nominal sliding resistance of precast concrete wall segments founded on sand. For footings on soil the eccentricity of loading at the strength limit state, based on factored loads, shall not exceed one-fourth ($1/4^{th}$) of the footing dimensions in either direction (LRFD Article 10.6.3.3). Sliding computations for resistance to lateral loads shall assume a maximum frictional coefficient of tan 30º at the foundation soil to soil infill interface and a maximum frictional coefficient of 0.8x(tan 30º) at the foundation soil to concrete module interface. Recommended values of sliding frictional coefficients are based on LRFD Article 11.11.4.2, Table 10.5.5.2.2-1 and Table 3.11.5.3-1.

The PCMG wall shall be constructed with a 1.5 foot thick layer of crushed stone placed vertically along the inside face of the wall units. The layer of crushed stone shall extend vertically from the bottom course of the wall units to the top course of the wall units. The crushed stone shall be separated from the surrounding backfill with erosion control geotextile.

The high water elevation shall be indicated on the retaining wall plans per the design requirements for hydrostatic conditions in Special Provision 635.

Bearing Resistance - The factored bearing resistance for at the strength limit state for the box culvert on compacted fill shall not exceed 8 ksf, however, the service limit state bearing resistance will govern. A factored bearing resistance of 6 ksf shall be used to control settlement when analyzing the service limit state as allowed in LRFD C10.6.2.6.1. In no instance shall the bearing stress exceed the nominal resistance of the structural concrete which may be taken as $0.3f'_c$. See Calculations for supporting documentation.

Scour and Riprap - The proposed box culvert will have PCMG wingwalls on all four corners. Concrete headwalls with nominal dimensions of 1 foot by 1 foot should be included in the design to retain riprap slopes. The slopes shall be armored with a 3-foot thick layer of plain riprap conforming to MaineDOT 703.26 Plain and Hand Laid Riprap of Special Provision 703 – Aggregates which is included in the original geotechnical report. The riprap shall be underlain by a Class 1 erosion control geotextile and a 1-foot layer of bedding material conforming to MaineDOT Standard Specification 703.19 Granular Borrow Material for Underwater Backfill. The toe of the riprap sections shall be constructed 1 foot below the streambed elevation. The riprap slopes should also be constructed in accordance with Special Provision 610 – Stone Fill, Riprap, Stone Blanket and Stone Ditch Protection as included in the original geotechnical report.

The box culvert shall be fitted with inlet and outlet cutoff walls that extend below the maximum depth of scour.

Settlement - No changes to original geotechnical report.

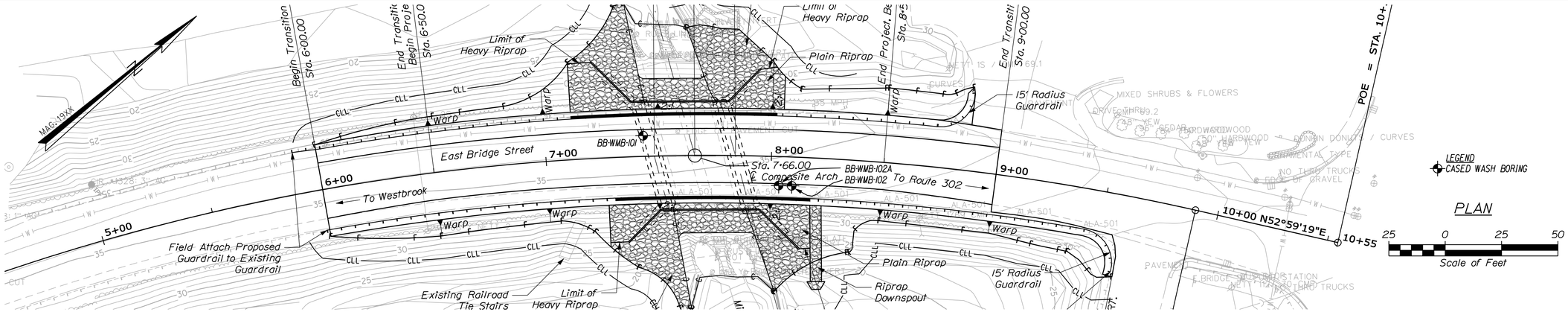
Frost Protection - No changes to original geotechnical report.

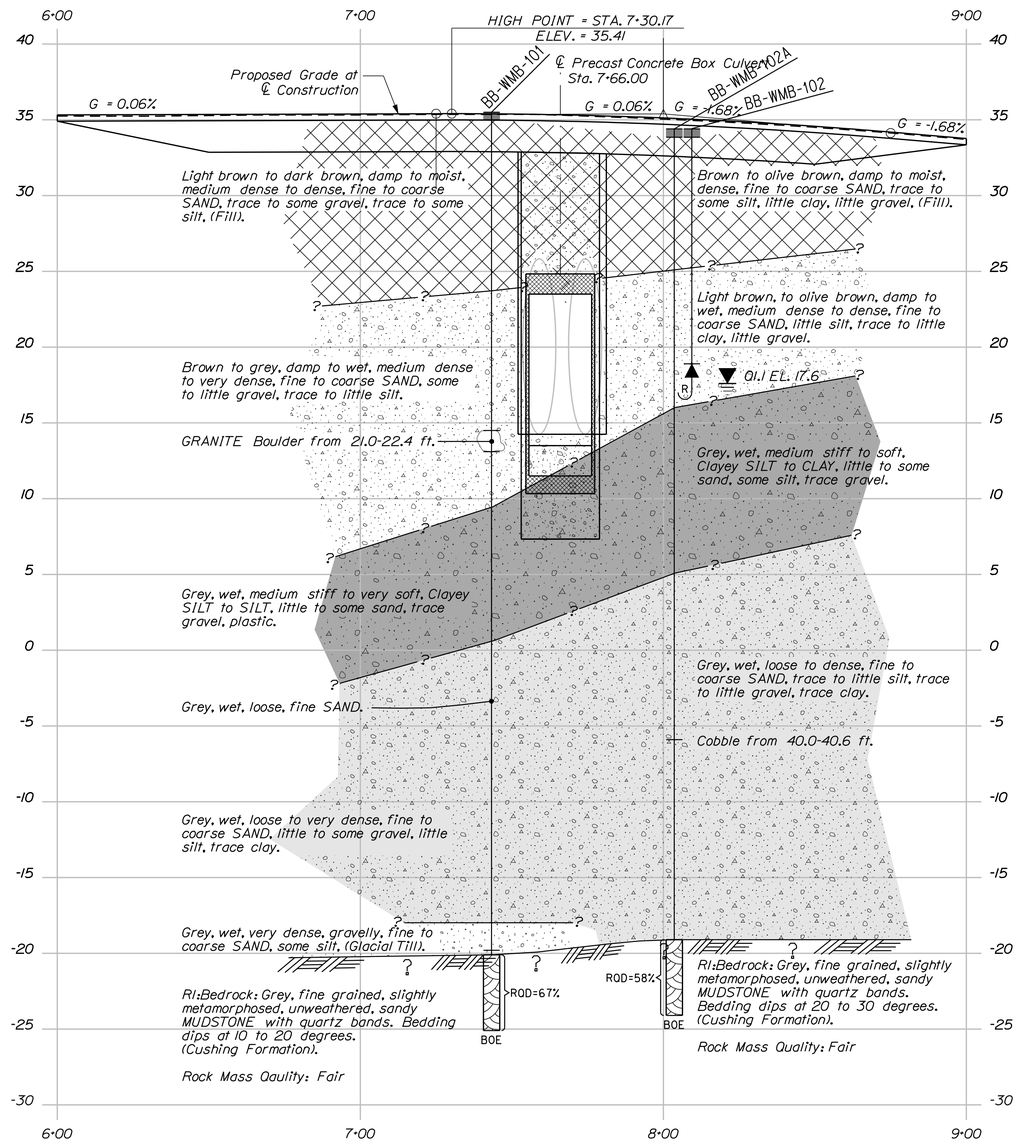
Seismic Design Considerations - In conformance with LRFD Article 3.10.1, seismic analysis is not required for buried structures, except where they cross active faults. There are no known active faults in Maine; therefore seismic analysis is not required.

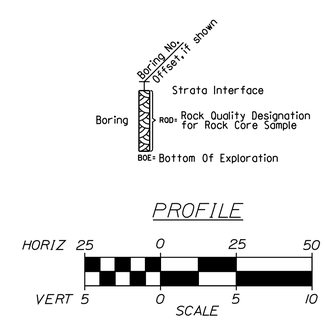
Construction Considerations - Construction of the proposed precast concrete box culvert will require soil excavation. Earth support systems will be required. The fill and native soils at the site will be susceptible to disturbance and rutting as a result of exposure to water and construction traffic. All subgrade surfaces should be protected from any unnecessary construction traffic. If disturbance and rutting occur, the Contractor shall remove and replace disturbed areas with compacted gravel borrow. Any cobbles or boulders encountered in excess of 6 inches shall be removed and replaced with compacted gravel borrow.

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.

Attachments:
Boring Location Plan and Interpretive Subsurface Profile
Calculations
Special Provision 534
Special Provision 635







Note: This generalized interpretive soil profile is intended to convey trends in subsurface conditions. The boundaries between strata are approximate and idealized, and have been developed by interpretations of widely spaced explorations and samples. Actual soil transitions may vary and are probably more erratic. For more specific information refer to the exploration logs.

STATE OF MAINE
DEPARTMENT OF TRANSPORTATION

BH-1676(100)X

PIN 16761.00

BRIDGE NO. 3987

BRIDGE PLANS

	BY	DATE
PROJ. MANAGER		
DESIGN-DETAILED	K.MAGUIRE	JAN 2010
CHECKED-REVIEWED		
DESIGN2-DETAILED2		
DESIGN3-DETAILED3		
REVISIONS 1		
REVISIONS 2		
REVISIONS 3		
REVISIONS 4		
FIELD CHANGES		

SIGNATURE

P.E. NUMBER

DATE

LITTLE BRIDGE
MILL BROOK
WESTBROOK CUMBERLAND COUNTY

BORING LOCATION PLAN &
INTERPRETIVE SUBSURFACE PROFILE

SHEET NUMBER
2
OF 3

Filename: ...\GEOTECH\MSTA\006_BLP&ISP1.dgn Division: GEOTECH Username: terry.white Date:1/19/2011

Box Culvert Bearing Resistance - Native Soils:

Part 1 - Service Limit State

Nominal and factored Bearing Resistance - box culvert on native clay silt and loose sands

Presumptive Bearing Resistance for Service Limit State ONLY

Reference: AASHTO LRFD Bridge Design Specifications 5th Edition
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: Inorganic silt, sandy or clayey silt, varved silt-clay-fine sand (ML-MH)

Based on corrected N-values ranging from WOR to 6 - Soils are very soft to medium stiff

Consistency In Place: very soft to medium stiff

Bearing Resistance: Ordinary Range (ksf) 2 to 6

Recommended Value of Use: 3 ksf

$$tsf := g \cdot \left(\frac{ton}{ft^2}\right)$$

Recommended Value: $3 \cdot ksf = 1.5 \cdot tsf$

Therefore: $q_{nom} := 1.5 \cdot tsf$

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

$q_{factored_bc} := 1.5 \cdot tsf$ or $q_{factored_bc} = 3 \cdot ksf$

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

Part 2 - Strength Limit State

Nominal and factored Bearing Resistance - box culvert on native clay silt and loose sands

Reference: Foundation Engineering and Design by JE Bowles Fifth Edition

Assumptions:

1. Box will be embedded approximately 5.0 feet. $D_f := 5.0 \cdot ft$
2. Assumed parameters for native soils: (Ref: Bowles 5th Ed Table 3-4)

   Saturated unit weight: $\gamma_s := 120 \cdot pcf$

   Dry unit weight: $\gamma_d := 115 \cdot pcf$

   Internal friction angle: $\phi_{ns} := 28 \cdot deg$

   Undrained shear strength: $c_{ns} := 0 \cdot psf$
3. Use Terzaghi strip equations as L>B
4. Effective stress analysis footing on ϕ-c soil (Bowles 5th Ed. Example 4-1 pg 231)

Depth to Groundwater table: $D_w := 0 \cdot ft$ Based on boring logs

Unit Weight of water: $\gamma_w := 62.4 \cdot pcf$

Box width: $B := 20.0 \cdot ft$

Terzaghi Shape factors from Table 4-1

For a strip footing: $s_c := 1.0$ $s_\gamma := 1.0$

Meyerhof Bearing Capacity Factors - Bowles 5th Ed. table 4-4 pg 223

For ϕ=28 deg

$N_c := 25.79$ $N_q := 14.7$ $N_\gamma := 11.2$

Nominal Bearing Resistance per Terzaghi equation (Bowles 5th Ed. Table 4-1 pg 220)

$q := D_f \cdot (\gamma_s - \gamma_w)$ $q = 0.144 \cdot tsf$

$q_{nominal} := c_{ns} \cdot N_c \cdot s_c + q \cdot N_q + 0.5(\gamma_s - \gamma_w)B \cdot N_\gamma \cdot s_\gamma$

$q_{nominal} = 5.3 \cdot tsf$

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

$q_{factored} := q_{nominal} \cdot \phi_b$ $q_{factored} = 2.4 \cdot tsf$ $q_{factored} = 4.8 \cdot ksf$

At Strength Limit State:

Recommend a limiting factored bearing resistance of 5 ksf for a 20 foot wide box.

At-Rest and Active Earth Pressure:

At-Rest Lateral Earth Pressure
from LRFD Article 3.11.5.2 pg 3-71

Effective friction angle of soil $\phi_f := 30 \cdot deg$

$K_o := 1 - \sin(\phi_f)$ $K_o = 0.5$

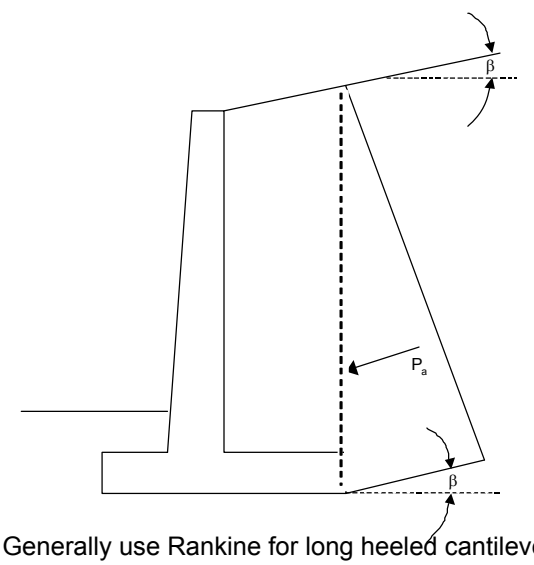
Active Earth Pressure - Rankine Theory
from MaineDOT Bridge Design Guide Section 3.6.5.2 pg 3-7

Soil Type 4 Properties from MaineDOT Bridge Design Guide (BDG)

unit weight: $\gamma_{type4} := 125 \cdot pcf$

Internal Friction Angle: $\phi_{type4} := 32 \cdot deg$

Cohesion: $c_{sand} := 0 \cdot psf$



Generally use Rankine for long heeled cantilever walls where the failure surface is un interrupted by the top of the wall system. The earth pressure is applied to a plane extending vertically up from the heel of the wall base and the weight of the soil on the inside of the vertical plane is considered as part of the wall weight. The failure sliding surface is not restricted by the top of the wall or the backface of the wall.

For cantilever walls with sloped backfill surface:

β = Angel of fill slope to the horizontal

$\beta := 0 \cdot deg$ assume horizontal backfill surface

$$K_{a_rankine_slope} := \frac{\cos(\beta) - \sqrt{\cos(\beta)^2 - \cos(\phi_{type4})^2}}{\cos(\beta) + \sqrt{\cos(\beta)^2 - \cos(\phi_{type4})^2}}$$

$K_{a_rankine_slope} = 0.31$

Pa is oriented at an angle of β to the vertical plane.

Bearing Resistance - Native Soils:

Part 1 - Service Limit State

Nominal and factored Bearing Resistance - PCMG units on native clayey silt to clay at north approach and medium dense to dense sand at south approach

Presumptive Bearing Resistance for Service Limit State ONLY

Reference: AASHTO LRFD Bridge Design Specifications 5th Edition
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)

Design for medium stiff clayey silt.

Type of Bearing Material: Inorganic silt, sandy or clayey silt, varved silt-clay-fine sand (ML-MH)

Consistency In Place: very soft to medium stiff

Bearing Resistance: Ordinary Range (ksf) 2 to 6

$tsf := g \cdot \left(\frac{ton}{ft^2}\right)$

Recommended Value of Use: 3 ksf

Recommended Value: $3 \cdot ksf = 1.5 \cdot tsf$

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

$q_{factored_bc} := 1.5 \cdot tsf$ or $q_{factored_bc} = 3 \cdot ksf$

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

Part 2 - Strength Limit State

Nominal and factored Bearing Resistance - PCMG units on native clayey silt to clay at north approach and medium dense to dense sand at south approach

Reference: Foundation Engineering and Design by JE Bowles Fifth Edition

Assumptions:

1. PCMG Walls will be embedded 5.0 feet for frost protection. $D_f := 5.0 \cdot ft$
2. Assumed parameters for clayey silt soils: (Ref: Bowles 5th Ed Table 3-4)
   - Saturated unit weight: $\gamma_s := 120 \cdot pcf$
   - Dry unit weight: $\gamma_d := 115 \cdot pcf$
   - Internal friction angle: $\phi_{ns} := 28 \cdot deg$
   - Undrained shear strength: $c_{ns} := 0 \cdot psf$
3. Use Terzaghi strip equations as L>B
4. Effective stress analysis footing on ϕ-c soil (Bowles 5th Ed. Example 4-1 pg 231)

Depth to Groundwater table: $D_w := 0 \cdot ft$ Based on boring logs

Unit Weight of water: $\gamma_w := 62.4 \cdot pcf$

Look at several footing widths

$$B := \begin{pmatrix} 5 \\ 8 \\ 10 \\ 12 \\ 15 \end{pmatrix} \cdot ft$$

Terzaghi Shape factors from Table 4-1

For a strip footing: $s_c := 1.0$ $s_\gamma := 1.0$

Meyerhof Bearing Capacity Factors - Bowles 5th Ed. table 4-4 pg 223

For ϕ=28 deg

$N_c := 25.79$ $N_q := 14.7$ $N_\gamma := 11.2$

Nominal Bearing Resistance per Terzaghi equation (Bowles 5th Ed. Table 4-1 pg 220)

$q := D_f \cdot (\gamma_s - \gamma_w)$ $q = 0.144 \cdot tsf$

$$q_{nominal} := c_{ns} \cdot N_c \cdot s_c + q \cdot N_q + 0.5(\gamma_s - \gamma_w)B \cdot N_\gamma \cdot s_\gamma$$

$$q_{nominal} = \begin{pmatrix} 2.9 \\ 3.4 \\ 3.7 \\ 4.1 \\ 4.5 \end{pmatrix} \cdot tsf$$

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

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

$$q_{factored} = \begin{pmatrix} 1.3 \\ 1.5 \\ 1.7 \\ 1.8 \\ 2 \end{pmatrix} \cdot tsf$$

Based on these footing widths

$$q_{factored} = \begin{pmatrix} 2.6 \\ 3.1 \\ 3.4 \\ 3.6 \\ 4.1 \end{pmatrix} \cdot ksf \qquad B := \begin{pmatrix} 5 \\ 8 \\ 10 \\ 12 \\ 15 \end{pmatrix} \cdot ft$$

At Strength Limit State:

Recommend a limiting factored bearing resistance of 3 ksf for walls less than 10 feet wide.
Recommend a limiting factored bearing resistance of 4 ksf for walls between 12 and 15 feet wide.

SPECIAL PROVISION
SECTION 534
PRECAST STRUCTURAL CONCRETE
(Precast Structural Concrete Arches, Box Culverts)

534.10 Description The Contractor shall design, manufacture, furnish, and install elements, precast structural concrete structures, arches, or box culverts and associated wings, headwalls, and appurtenances, in accordance with the contract documents.

534.20 Materials Structural precast elements for the arch or box culvert and associated precast elements shall meet the requirements of the following Subsection:

Structural Precast Concrete Units	712.061

Grout, concrete patching material, and geotextiles shall be one of the products listed on the Department's list of prequalified materials, unless otherwise approved by the Department.

Box culvert bedding and backfill material shall consist of Standard Specification 703.19, Granular Borrow, Material for Underwater Backfill, with the additional requirement that the maximum particle size be limited to 4 inches.

534.30 Design Requirements The Contractor shall design the precast structural concrete structure in accordance with the AASHTO LRFD Bridge Design Specifications 5th Edition 2010. The design live load shall be as follows: *modified HL-93 Strength I for LRFD method. *(modify HL-93 by increasing HS-20 design truck wheel loads by a factor of 1.25)

The Contractor shall submit design calculations and shop drawings for the precast structure to the Department for approval. A Registered Professional Engineer, licensed in accordance with State of Maine laws, shall sign and seal all design calculations and drawings. The Contractor shall submit a bridge rating on the Department's Standard Bridge Rating Summary Sheet with the design calculations. Drawings shall conform with Section 105.7 - Working Drawings.

The Contractor shall submit the following items for review by the Resident at least ten working days prior to production:

A) The name and location of the manufacturer.
B) Method of manufacture and material certificates.
C) Description of method of handling, storing, transporting, and erecting the members.
D) Shop Drawings with the following minimum details:

1) Fully dimensioned views showing the geometry of the members, including all projections, recesses, notches, openings, block outs, and keyways.
2) Details and bending schedules of reinforcing steel including the size, spacing, and location. Reinforcing provided under lifting devices shall be shown in detail.
3) Details and locations of all items to be embedded.
4) Total mass (weight) of each member.

534.40 Construction Requirements The applicable provisions of Subsection 535.10 - Forms and Casting Beds and Subsection 535.20 – Finishing Concrete and Repairing Defects shall be met.

Manufacture of Precast Units The internal dimensions shall not vary by more than 1 percent from the design dimensions or 1 ½ inches, whichever is less. The haunch dimensions shall not vary by more than ¾ inch from the design dimension. The dimension of the legs shall not vary by more than ¼ inch from the dimension shown on the approved shop drawings.

The slab and wall thickness shall not be less than the design thickness by more than ¼ inch. A thickness greater than the design thickness shall not be cause for rejection.

Variations in laying lengths of two opposite surfaces shall not be more than ⅝ inch in any section, except where beveled ends for laying of curves are specified.

The under-run in length of any section shall not be more than ½ inch.

The cover of concrete over the outside circumferential reinforcement shall be 2 inch minimum. The concrete cover over the inside reinforcement shall be 1 ½ inch minimum. The clear distance of the end of circumferential wires shall not be less than 1 inch or more than 2 inch from the end of the sections. Reinforcement shall be single or multiple layers of welded wire fabric or a single layer of deformed billet steel bars.

Welded wire fabric shall meet the space requirements and contain sufficient longitudinal wires extending through the section to maintain the shape and position of the reinforcement. Longitudinal distribution reinforcement may be welded wire fabric or deformed billet steel bars which meet the spacing requirements. The ends of the longitudinal distribution reinforcement shall be not more than 3 inches from the ends of the sections.

The inside circumferential reinforcing steel for the haunch radii or fillet shall be bent to match the radii or fillets of the forms.

Tension splices in the reinforcement will not be permitted. For splices other than tension splices, the overlap shall be a minimum of 12 inches for welded wire fabric or billet steel bars. The spacing center to center of the circumferential wires in a wire fabric sheet shall be not less than 2 inches or more than 4 inches. For the wire fabric, the spacing center to center of the longitudinal wires shall not be more than 8 inches. The spacing center to center of the longitudinal distribution steel for either line of reinforcing in the top slab shall be not more than 15 inches.

The members shall be free of fractures. The ends of the members shall be normal to the walls and centerline of the section, within the limits of variation provided, except where beveled ends are specified. The surfaces of the members shall be a smooth steel form or troweled surface finish, unless a form liner is specified. The ends and interior of the assembled structure shall make a continuous line of members with a smooth interior surface.

Defects which may cause rejection of precast units include the following:

1) Any discontinuity (crack or rock pocket etc.) of the concrete which could allow moisture to reach the reinforcing steel.
2) Rock pockets or honeycomb over 6 inch² in area or over 1 inch deep.
3) Edge or corner breakage exceeding 12 inches in length or 1 inch in depth.
4) Extensive fine hair cracks or checks.
5) Any other defect that clearly and substantially impacts the quality, durability, or maintainability of the structure as measured by accepted industry standards.

The Contractor shall store and transport members in a manner to prevent cracking or damage. The Contractor shall not place precast members in an upright position until a compressive strength of at least 4350 psi is attained.

Installation of Precast Units The Contractor shall not ship precast members until sufficient strength has been attained to withstand shipping, handling and erection stresses without cracking, deformation, or spalling (but in no case less than 4350 psi).

The Contractor shall set precast members on ½ inch neoprene pads during shipment to prevent damage to the section legs. The Contractor shall repair any damage to precast members resulting from shipping or handling by saw cutting a minimum of ½ inch deep around the perimeter of the damaged area and placing a polymer-modified cementitious patching material.

When footings are required, the Contractor shall install the precast members on concrete footings that have reached a compressive strength of at least 2900 psi. The Contractor shall construct the completed footing surface to the lines and grades shown on the plans. When checked with a 10 feet straightedge, the surface shall not vary more than ¼ inch in 10 feet. The footing keyway shall be filled with a non-shrink flowable cementitious grout with a design compressive strength of at least 5075 psi.

The Contractor shall fill holes that were cast in the units for handling, with either Portland cement mortar, or with precast plugs secured with Portland cement mortar or other approved adhesive. The Contractor shall completely fill the exterior face of joints between precast members with an approved material and cover with a minimum 12 inch wide joint wrap. The surface shall be free of dirt and deleterious materials before applying the filler material and joint wrap. The Contractor shall install the external wrap in one continuous piece over each member joint, taking care to keep the joint wrap in place during backfilling. The Contractor shall seal the joints between the end unit and attached elements with a non-woven geotextile. The Contractor shall install and tighten the bolts fastening the connection plate(s) between the elements that are designed to be fastened together as designated by the manufacturer. Final assembly shall be approved by the manufacturer's representative prior to backfilling.

The Contractor shall place and compact the bedding material as shown on the plans prior to lifting and setting the box culvert sections. The Contractor shall backfill the structure in accordance with the manufacturer's instructions and the Contract Documents. The Contractor shall uniformly distribute backfill material in layers of not more than 8 inches in depth, loose measure, and thoroughly compact each layer using approved compactors before successive layers are placed. The Contractor shall compact the Granular Borrow bedding

and backfill in accordance with Section 203.12 - Construction of Earth Embankment with Moisture and Density Control, except that the minimum required compaction shall be 92 percent of maximum density as determined by AASHTO T180, Method C or D. The Contractor shall place and compact backfill without disturbance or displacement of the wall units, keeping the fill at approximately the same elevation on both sides of the structure. Whenever a compaction test fails, the Contractor shall not place additional backfill over the area until the lift is re-compacted and a passing test achieved.

The Contractor shall use hand-operated compactors within 5 feet of the precast structure as well as over the top until it is covered with at least 12 inches of backfill. Equipment in excess of 12 ton shall not use the structure until a minimum of 24 inches of backfill cover is in place and compacted.

534.50 Method of Measurement The Department will measure Precast Structural Concrete Arch or Box Culvert for payment per Lump Sum each, complete in place and accepted.

534.60 Basis of Payment The Department will pay for the accepted quantity of Precast Structural Concrete Arch or Box Culvert at the Contract Lump Sum price, such payment being full compensation for all labor, equipment, materials, professional services, and incidentals for furnishing and installing the precast concrete elements and accessories. Falsework, reinforcing steel, jointing tape, grout, cast-in-place concrete fill or grout fill for anchorage of precast wings and/or other appurtenances is incidental to the Lump Sum pay item. Cast-in-place concrete, reinforcing steel in cast-in-place elements, excavation, backfill material, and membrane waterproofing will be measured and paid for separately under the provided Contract pay items. Pay adjustments for quality level will not be made for precast concrete.

Payment will be made under:

Pay Item	Pay Unit
534.71 Precast Concrete Box Culvert	Lump Sum

SPECIAL PROVISION
SECTION 635
PREFABRICATED CONCRETE MODULAR GRAVITY WALL

The following replaces Section 635 in the Standard Specifications in its entirety:

635.01 Description. This work shall consist of the construction of a prefabricated modular reinforced concrete gravity wall in accordance with these specifications and in reasonably close conformance with the lines and grades shown on the plans, or established by the Resident.

Included in the scope of the Prefabricated Concrete Modular Gravity Wall construction are**:** all grading necessary for wall construction, excavation, compaction of the wall foundation, backfill, construction of leveling pads, placement of geotextile, segmental unit erection, and all incidentals necessity to complete the work.

The Prefabricated Concrete Modular Gravity Wall design shall follow the general dimensions of the wall envelope shown in the contract plans. The top of the leveling pad shall be located at or below the theoretical leveling pad elevation. The minimum wall embedment shall be at or below the elevation shown on the plans. The top of the face panels shall be at or above the top of the panel elevation shown on the plans.

The Contractor shall require the design-supplier to supply an on-site, qualified experienced technical representative to advise the Contractor concerning proper installation procedures. The technical representative shall be on-site during initial stages of installation and thereafter shall remain available for consultation as necessary for the Contractor or as required by the Resident. The work done by this representative is incidental.

635.02 Materials. Materials shall meet the requirements of the following subsections of Division 700 - Materials:

Gravel Borrow	703.20
Preformed Expansion Joint Material	705.01
Reinforcing Steel	709.01
Structural Pre-cast Concrete Units	712.061
Drainage Geotextile	722.02

The Contractor is cautioned that all of the materials listed are not required for every Prefabricated Concrete Modular Gravity Wall. The Contractor shall furnish the Resident a Certificate of Compliance certifying that the applicable materials comply with this section of the specifications. Materials shall meet the following additional requirements:

Concrete Units:

Tolerances. In addition to meeting the requirements of 712.061, all prefabricated units shall be manufactured with the following tolerances. All units not meeting the listed tolerances will be rejected.

1. All dimensions shall be within (edge to edge of concrete) ±3/16 inch.

2. Squareness. The length differences between the two diagonals shall not exceed 5/16 inch.
3. Surface Tolerances. For steel formed surfaces, and other formed surface, any surface defects in excess of 0.08 inch in 4 feet will be rejected. For textured surfaces, any surface defects in excess of 5/16 inch in 5 feet shall be rejected.

Joint Filler. (where applicable) Joints shall be filled with material approved by the Resident and supplied by the approved Prefabricated Concrete Modular Gravity Wall supplier. 4 inch wide, by 0.5 inch thick preformed expansion joint filler shall be placed in all horizontal joints between facing units. In all vertical joints, a space of 0.25 inch shall be provided. All Preformed Expansion Joint Material shall meet the requirements of subsection 502.03.

Woven Drainage Geotextile. Woven drainage geotextile 12 inches wide shall be bonded with an approved adhesive compound to the back face, covering all joints between units, including joints abutting concrete structures. Geotextile seam laps shall be 6 inches minimum. The fabric shall be secured to the concrete with an adhesive satisfactory to the Resident. Dimensions may be modified per the wall supplier's recommendations, with written approval of the Resident.

Concrete Shear Keys. (where applicable) Shear keys shall have a thickness at least equal to the pre-cast concrete stem.

Concrete Leveling Pad. Cast-in-place concrete shall be Fill Concrete conforming to the requirements of Section 502 Structural Concrete. The horizontal tolerance on the surface of the pad shall be 0.25 inch in 10 feet. Dimensions may be modified per the wall supplier's recommendations, with written approval of the Resident.

Backfill and Bedding Material. Bedding and backfill material placed behind and within the reinforced concrete modules shall be gravel borrow conforming to the requirements of Subsection 703.20. The backfill materials shall conform to the following additional requirements: the plasticity index (PI) as determined by AASHTO T90 shall not exceed 6. Compliance with the gradation and plasticity requirements shall be the responsibility of the Contractor, who shall furnish a copy of the backfill test results prior to construction.

The backfilling of the interior of the wall units and behind the wall shall progress simultaneously. The material shall be placed in layers not over 8 inches in depth, loose measure, and thoroughly compacted by mechanical or vibratory compactors. Puddling for compaction will not be allowed.

Materials Certificate Letter. The Contractor, or the supplier as his agent, shall furnish the Resident a Materials Certificate Letter for the above materials, including the backfill material, in accordance with Section 700 of the Standard Specifications. A copy of all test results performed by the Contractor or his supplier necessary to assure contract compliance shall also be furnished to the Resident. Acceptance will be based upon the materials Certificate Letter, accompanying test reports, and visual inspection by the Resident.

635.03 Design Requirements. The Prefabricated Concrete Modular Gravity Wall shall be designed and sealed by a licensed Professional Engineer registered in accordance with the laws

of the State of Maine. The design to be performed by the wall system supplier shall be in accordance with AASHTO LRFD Bridge Design Specifications, current edition, except as required herein. Design shall consider Strength and Extreme Limit States. Thirty days prior to beginning construction of the wall, the design computations shall be submitted to the Resident for review by the Department. Design calculations that consist of computer generated output shall be supplemented with at least one hand calculation and graphic demonstrating the design methodology used. Design calculations shall provide thorough documentation of the sources of equations used and material properties. The design by the wall system supplier shall consider the stability of the wall as outlined below:

A. Stability Analysis:

1. Overturning: Location of the resultant of the reaction forces shall be within the middle one-half of the base width.
2. Sliding: $R_R \geq \gamma_{p(max)} \cdot (EH+ES)$

   Where: R_R = Factored Sliding Resistance

   $\gamma_{p(max)}$ = Maximum Load Factor

   EH = Horizontal Earth Pressure

   ES = Earth Surcharge (as applicable)
4. Bearing Pressure: $q_R \geq$ Factored Bearing Pressure

   Where: q_R = Factored Bearing Resistance, as shown on the plans

   Factored Bearing Pressure = Determined considering the applicable loads and load factors which result in the maximum calculated bearing pressure.
5. Pullout Resistance: Pullout resistance shall be determined using nominal resistances and forces. The ratio of the sum of the nominal resistances to the sum of the nominal forces shall be greater than, or equal to, 1.5.

Traffic impact loads transmitted to the wall through guardrail posts shall be calculated and applied in compliance with LRFD Section 11, where Article 11.10.10.2 is modified such that the upper 3.5 feet of concrete modular units shall be designed for an additional horizontal load of γP_{H1}, where γP_{H1}=300 lbs per linear foot of wall.

B. Backfill and Wall Unit Soil Parameters. For overturning and sliding stability calculations, earth pressure shall be assumed acting on a vertical plane rising from the back of the lowest wall stem. For overturning, the unit weight of the backfill within the wall units shall be limited to 96 pcf. For sliding analyses, the unit weight of the backfill within the wall units can be assumed to be 120 pcf. Both analyses may assume a friction angle of 34 degrees for backfill within the wall units.

These unit weights and friction angles are based on a wall unit backfill meeting the requirements for select backfill in this specification. Backfill behind the wall units shall be assumed to have a unit weight of 120 pcf and a friction angle of 30 degrees. The friction angle of the foundation soils shall be assumed to be 30 degrees unless otherwise noted on the plans.

C. Internal Stability. Internal stability of the wall shall be demonstrated using accepted methods, such as Elias' Method, 1991. Shear keys shall not contribute to pullout resistance. Soil-to-soil frictional component along stem shall not contribute to pullout

resistance. The failure plane used to determine pullout resistance shall be found by the Rankine theory only for vertical walls with level backfills. When walls are battered or with backslopes > 0 degrees are considered, the angle of the failure plane shall be per Jumikus Method. For computation of pullout force, the width of the backface of each unit shall be no greater than 4.5 feet. A unit weight of the soil inside the units shall be assumed no greater than 120 pcf when computing pullout. Coulomb theory may be used.

D. External loads which affect the internal stability such as those applied through piling, bridge footings, traffic, slope surcharge, hydrostatic and seismic loads shall be accounted for in the design.

E. The maximum calculated factored bearing pressure under the Prefabricated Concrete Modular Gravity block wall shall be clearly indicated on the design drawings.

F. Stability During Construction. Stability during construction shall be considered during design, and shall meet the requirements of the AASHTO LRFD Bridge Design Specifications, Extreme Limit State.

G. Hydrostatic forces. Unless specified otherwise, when a design high water surface is shown on the plans at the face of the wall, the design stresses calculated from that elevation to the bottom of wall must include a 3 feet minimum differential head of saturated backfill. In addition, the buoyant weight of saturated soil shall be used in the calculation of pullout resistance.

H. Design Life. The wall design life shall be a minimum of 75 years.

I. Not more than two vertically consecutive units shall have the same stem length, or the same unit depth. Walls with units with extended height curbs shall be designed for the added earth pressure. A separate computation for pullout of each unit with extended height curbs, or extended height coping, shall be prepared and submitted in the design package described above.

635.04 Submittals. The Contractor shall supply wall design computations, wall details, dimensions, quantities, and cross sections necessary to construct the wall. Thirty (30) days prior to beginning construction of the wall, the design computations and wall details shall be submitted to the Resident for review. The fully detailed plans shall be prepared in conformance with Subsection 105.7 of the Standard Specifications and shall include, but not be limited to the following items:

A. A plan and elevation sheet or sheets for each wall, containing the following: elevations at the top of leveling pads, the distance along the face of the wall to all steps in the leveling pads, the designation as to the type of prefabricated module, the distance along the face of the wall to where changes in length of the units occur, the location of the original and final ground line.

B. All details, including reinforcing bar bending details, shall be provided. Bar bending details shall be in accordance with Department standards.

C. All details for foundations and leveling pads, including details for steps in the leveling pads, as well as allowable and actual maximum bearing pressures shall be provided.

D. All prefabricated modules shall be detailed. The details shall show all dimensions necessary to construct the element, and all reinforcing steel in the element.

E. The wall plans shall be prepared and stamped by a Professional Engineer. Four sets of design drawings and detail design computations shall be submitted to the Resident.

F. Four weeks prior to the beginning of construction, the contractor shall supply the Resident with two copies of the design-supplier's Installation Manual. In addition, the Contractor shall have two copies of the Installation Manual on the project site.

635.05 Construction Requirements

Excavation. The excavation and use as fill disposal of all excavated material shall meet the requirements of Section 203 -- Excavation and Embankment, except as modified herein.

Foundation. The area upon which the modular gravity wall structure is to rest, and within the limits shown on the submitted plans, shall be graded for a width equal to, or exceeding, the length of the module. Prior to wall and leveling pad construction, this foundation material shall be compacted to at least 95 percent of maximum laboratory dry density, determined using AASHTO T180, Method C or D. Frozen soils and soils unsuitable or incapable of sustaining the required compaction, shall be removed and replaced.

A concrete leveling pad shall be constructed as indicated on the plans. The leveling pad shall be cast to the design elevations as shown on the plans, or as required by the wall supplier upon written approval of the Resident. Allowable elevation tolerances are +0.01 feet and -0.02 feet from the design elevations. Leveling pads which do not meet this requirement shall be repaired or replaced as directed by the Resident at no additional cost to the Department. Placement of wall units may begin after 24 hours curing time of the concrete leveling pad.

Method and Equipment. Prior to erection of the Prefabricated Concrete Modular Gravity Wall, the Contractor shall furnish the Resident with detailed information concerning the proposed construction method and equipment to be used. The erection procedure shall be in accordance with the manufacturer's instructions. Any pre-cast units that are damaged due to handling will be replaced at the Contractor's expense.

Installation of Wall Units. A field representative from the wall system being used shall be available, as needed, during the erection of the wall. The services of the representative shall be at no additional cost to the Department. Vertical and horizontal joint fillers shall be installed as shown on the plans.

The maximum offset in any unit joint shall be 3/4 inch. The overall vertical tolerance of the wall, plumb from top to bottom, shall not exceed 1/2 inch per 10 feet of wall height. The

prefabricated wall units shall be installed to a tolerance of plus or minus 3/4 inch in 10 feet in vertical alignment and horizontal alignment.

Select Backfill Placement. Backfill placement shall closely follow the erection of each row of prefabricated wall units. The Contractor shall decrease the lift thickness if necessary to obtain the specified density. The maximum lift thickness shall be 8 inches (loose). Gravel borrow backfill shall be compacted in accordance with Subsection 203.12 except that the minimum required compaction shall be 92 percent of maximum density as determined by AASHTO T180 Method C or D. Backfill compaction shall be accomplished without disturbance or displacement of the wall units. Sheepsfoot rollers will not be allowed. Whenever a compaction test fails, no additional backfill shall be placed over the area until the lift is recompacted and a passing test achieved.

The moisture content of the backfill material prior to and during compaction shall be uniform throughout each layer. Backfill material shall have a placement moisture content less than or equal to the optimum moisture content. Backfill material with a placement moisture content in excess of the optimum moisture content shall be removed and reworked until the moisture content is uniform and acceptable throughout the entire lift. The optimum moisture content shall be determined in accordance with AASHTO T180, Method C or D. At the end of the day's operations, the Contractor shall shape the last level of backfill so as to direct runoff of rain water away from the wall face.

635.06 Method of Measurement. Prefabricated Concrete Modular Gravity Wall will be measured by the square meter of front surface not to exceed the dimensions shown on the contract plans or authorized by the Resident. Vertical and horizontal dimensions will be from the edges of the facing units. No field measurements for computations will be made unless the Resident specifies, in writing, a change in the limits indicated on the plans.

635.07 Basis of Payment. The accepted quantity of Prefabricated Concrete Modular Gravity Retaining Wall will be paid for at the contract unit price per square meter complete in place. Payment shall be full compensation for furnishing all labor, equipment and materials including excavation, foundation material, backfill material, pre-cast concrete units hardware, joint fillers, woven drainage geotextile, cast-in-place coping or traffic barrier and technical field representative. Cost of cast-in-place concrete for leveling pad will not be paid for separately, but will be considered incidental to the Prefabricated Concrete Modular Gravity Wall.

There will be no allowance for excavating and backfilling for the Prefabricated Concrete Modular Gravity Wall beyond the limits shown on the approved submitted plans, except for excavation required to remove unsuitable subsoil in preparation for the foundation, as approved by the Resident. Payment for excavating unsuitable material shall be full compensation for all costs of pumping, drainage, sheeting, bracing and incidentals for proper execution of the work.

Payment will be made under:

Pay Item	Pay Unit
635.14 Prefabricated Concrete Modular Gravity Wall	Square Foot