TYPE	YEAR	PROJECT NO.	SHEET NO.
CONST.	2014	NH-I-40-1(283)20	

Retaining Wall Design Notes

Unless specifically stated otherwise in the contract plans, the bidding for, the design of and the construction of retaining walls shown in the plans shall be governed by the *Tennessee Department of Transportation Special Provision 624 Regarding Retaining Walls*. This Special Provision shall be considered as one of those documents which the Bidder/Contractor has examined and made himself familiar with as described in *Section 102.04 – Examination of the Site, the Work, the Plans, and the Specifications in the TDOT Standard Specifications for Road and Bridge Construction.*

Excavation for the wall and/or its footing shall not be accomplished until the Contractor has submitted wall designs and calculations and has been issued an approved set of wall plans and has labor and material resources available to begin and continue wall construction immediately after excavation.

This wall shall be designed in accordance with LRFD design procedures and requirements as described in 1) AASHTO LRFD Bridge Design Specifications, 2007 and Interims and 2) Publication FHWA-NHI-10-024/FHWA GEC 011, *Design and Construction of Mechanically Stabilized Earth Walls and Reinforced Soil Slopes, November 2009* for MSE walls.

For proprietary wall systems that have been approved as shown in Special Provision 624, the Wall Designer shall be responsible for providing wall designs incorporating materials and components (i.e. reinforcement connection devices, specific manufacturer and properties of geogrid) as was originally submitted and approved by TDOT. If a material and/or component of the wall system have been modified from the originally approved system, a wall design and set of plans and calculations for this wall system cannot be submitted for review and approval until the Wall System Designer who originally submitted the wall system for approval by TDOT submits a request for re-approval utilizing the modified elements of the wall. This submittal does not guarantee approval of the modified system. If this re-approval process does not meet the Contractor's schedule or if the modified system is not approved, the Contractor/Wall Designer shall provide a wall design for one of the approved systems at no change in contract price for the retaining wall and no change in project schedule requirements will be allowed.

The Wall Designer shall provide retaining wall plans, details and calculations as required by Special Provision 624 and as required herein.

- The Wall Designer shall utilize the Geotechnical Parameters and Resistance Factors as provided for each project retaining wall on the Wall Concept Sheet and related Retaining Wall Sheets to prepare and submit design calculations. Load Factors and other pertinent design requirements provided in AASHTO LRFD Bridge Design Specifications, 2007 and Interims shall be used for non-MSE walls and in Publication FHWA-NHI-10-024/FHWA GEC 011, *Design and Construction of Mechanically Stabilized Earth Walls and Reinforced Soil Slopes, November 2009* for MSE walls.

- Calculations for both internal and external stability (sliding, eccentricity, and bearing capacity-global stability and settlement being the exceptions) shall be provided for each critical wall section which demonstrates the required Capacity to Demand Ratio of 1.0 is met utilizing the design parameters provided. For MSE walls, the Wall Designer must adjust the reinforcement lengths beyond those minimum required lengths, if required, to meet both internal and external requirements. The Wall Designer/Contractor plans must include any foundation improvements as required herein on the Wall Designer/Contractor's wall elevation views and any cross-sectional detail drawings.

- Unless otherwise stated, the Wall Designer can assume that minimum global stability and settlement criteria is achieved with a wall design meeting other minimum external stability requirements and assuming wall foundation conditions are met. While the Wall Designer's design must demonstrate compliance with external stability requirements as discussed above, the Wall Designer may provide certification (by signing and stamping by Professional Engineer registered in State of Tennessee) of the wall plans and calculations **for internal stability only**.

- Load Combinations Strength I, Extreme Event I, and Extreme Event II as given in Table 4-1 of Publication FHWA-NHI-10-024/FHWA GEC 011, *Design and Construction of Mechanically Stabilized Earth Walls and Reinforced Soil Slopes, November 2009* for MSE walls shall be evaluated for MSE walls. Load Combinations for other wall types shall be as given in AASHTO LRFD Bridge Design Specifications, 2007 and Interims.

Acceptable Wall Types

The retaining wall shall be one of the wall types listed below. For retaining wall systems listed as Bin Wall, Crib Wall, MSE (either segmental panel or Modular Block) and Ground Anchor Wall, the specific Wall System Supplier/Installer shall be one of those listed as Pre–approved in the Special Provision 624.

Cast-in-Place Concrete Gravity Wall
Cast-in-Place Concrete Cantilever Wall
Mechanically Stabilized Earth (MSE) Wall – Segmental Precast
Mechanically Stabilized Earth (MSE) Wall – Modular Block

TABLE 1-DESIGN REQUIREMENTS AND PARAMETERS

Description	Value-MSE Walls	Value-Other Walls	Note *
Design Life	75 Years	75 Years	
Seismic Acceleration Coefficient, A_S	0.398	0.398	
Effective (Drained) Friction Angle			
Retained Backfill-Unclassified site or borrow soil	26°	26°	
Retained Backfill-Select Backfill	34° to max 40°	34° to max 40°	1
Reinforced Backfill	34° to max 40°	NOT APPLICABLE	
Unit Weight-			
Unclassified site or borrow soil	120 pounds per cubic foot	120 pounds per cubic foot	
Select Backfill Material	Varies	Varies	1A
Minimum Length of soil reinforcement, B	Greater of 0.7H min or 8-ft or as specified in the plans	NOT APPLICABLE	2,2A
Limiting eccentricity	B/4 (soil), 3/8B (rock)	B/4 (soil), 3/8B (rock)	
Coefficient of Sliding Friction	See Table 2 or 3	See Table 2 or 3	3
Nominal Bearing Capacity	See Table 2 or 3	See Table 2 or 3	3
Resistance Factors			
Sliding-Static	1.0	0.85	4
Sliding-Combined Static+Earthquake	1.0	1.0	4
Bearing-Static	0.65	0.45	5
Bearing- Combined Static+Earthquake	1.0	1.0	
Pullout resistance			
Static	0.90	NOT APPLICABLE	6
Combined static/earthquake	1.20	NOT APPLICABLE	6
Tensile resistance of metallic reinforcements and connectors		NOT APPLICABLE	
Static -Strip reinforcement -Grid reinforcement	 0.75 0.65	NOT APPLICABLE	 7 7,8
Combined static/earthquake -Strip reinforcement - Grid reinforcement	 1.00 0.85	 NOT APPLICABLE	 7 7,8
Tensile resistance of geosynthetic reinforcements and connectors		NOT APPLICABLE	
Static	0.90	NOT APPLICABLE	
Combined static/earthquake	1.20	NOT APPLICABLE	
*Refer to Table 1.1 for notes.			

TABLE 1.1
NOTES FOR TABLE 1

#	Note
1	A minimum friction angle of 34 degrees can be assumed for material meeting specifications in Section F, Part 1, and Item e of *Tennessee Department of Transportation Special Provision 624 Regarding Retaining Walls.* A higher friction angle can be utilized if the Contractor submits independent testing and it is verified by TDOT. However, in no case shall the friction angle for analysis exceed 40-degrees.
1A	Select Backfill unit weight to be determined by Contractor/Designer depending on actual backfill material used. Select backfill is defined as material meeting specifications in Section F, Part 1, and Item e of *Tennessee Department of Transportation Special Provision 624 Regarding Retaining Walls*. In order to utilize ϕ for select backfill design, select backfill must be placed for a minimum zone formed by a 1:1 slope from 2 feet behind the bottom of back of wall footing or reinforced soil zone for MSE walls up to finished grade.
2	H is the design height of the wall and is defined as the difference in elevation between from the finished grade at the top of the wall and the top of leveling pad. The top of the leveling pad shall always be below the minimum embedment reference line as indicated on the plans for that location. The length of the soil reinforcement, B, is measured from the backface of the wall facing unit. In case of grid type reinforcements the length of the soil reinforcement is measured from the backface of the wall facing unit to the last full transverse member. For modular block facing units, the total length of the reinforcement, Br as measured from the front face of the wall is the length B as defined above plus the width of the modular block unit (the horizontal dimension of the block unit measured perpendicular to the wall face).
2A	Wall Designer must adjust the reinforcement lengths beyond those minimum required lengths, if required, to meet both internal and external (global stability being the exception) stability requirements.
3	These values will be provided in Table 2 and/or 3
4	Passive resistance shall **NOT** be considered in evaluation of sliding resistance.
5	For all limit states, the design loading for the MSE retaining wall system shall not exceed the factored general and local bearing resistance specified in Tables 2 or 3.
6	Live load due to vehicular traffic shall be included in the computations to determine the maximum tensile forces in reinforcement layers, but shall be neglected in the computations for pullout resistance.
7	Apply to gross cross-section less sacrificial area. For sections with holes, reduce gross area in accordance with Article 6.8.3 of AASHTO (2007) and apply to net section less sacrificial area.
8	Applies to grid reinforcements connected to a rigid facing element, e.g., a concrete panel or block. For grid reinforcements connected to a flexible facing mat or which are continuous with the facing mat, use the resistance factor for strip reinforcements.
	Unless otherwise specified, all resistance factors shall be taken as 1.0 when investigating an extreme event limit state.

Table 2 – Maximum Allowable Net Soil Bearing

Condition	Cantilever or Gravity Wall	MSE Wall
Stiff to Very Stiff Fine-Grained Soil or Properly Compacted Fill	3,000 PSF	3,000 PSF

Construction Slopes

Excavation for the wall and/or its footing shall not be accomplished until the contractor has labor and material resources available to begin and continue wall construction immediately after excavation. The excavation for the retaining wall foundation should be made in accordance with the requirements of Section 204-Structure Excavation, Foundation Preparation and Backfill, TDOT Standard Specifications for Road and Bridge Construction dated March 1, 2006 as specified therein for Bridges, Box Culverts and Other Major Structures (Section 204). This will involve some excavation of soil near the base of the proposed wall. Once the foundation subgrade is at design grade, further construction should be withheld pending inspection and approval of the foundation subgrade by the Engineer as specified in Section 204.

All temporary construction slopes shall be placed at a maximum 1:1 slope in soil and shall not be left open without shoring for any longer than absolutely necessary. The contractor building the wall shall ensure that these temporary back slopes are not and do not become unstable. If a slope is unstable, becomes unstable, is cut steeper than a 1:1 slope or is unacceptable for another reason, then temporary shoring shall be used.

Settlement

Based on the known subsurface conditions and site geology, laboratory testing and past experience, we anticipate that properly designed and constructed retaining wall foundations should experience maximum total settlements on the order of one inch. Differential settlements along the wall are expected to be on the order of ¾ inches per 100 feet of wall.

Seismic Loading on Walls

Regarding lateral earth pressures on below grade walls due to earthquake forces, estimates of the magnitude of these forces may be made in accordance with methods outlined in the AASHTO LRFD Bridge Design Specifications, 2008 Edition Interim, Appendix A11 Seismic Design of Abutments and Gravity Retaining Structures.

For free standing structures such as gravity or cantilever walls, we have provided design recommendations based on relatively small lateral displacements. We have assumed that the below grade wall will be able to yield sufficiently to allow active pressure conditions to be mobilized, the select granular backfill will be cohesionless with a friction angle of 35 degrees, the extent of the select granular backfill will meet the requirements discussed previously in this report, and the backfill will be unsaturated, so that liquefaction problems will not arise. The retaining wall height (or depth) below the highest ground surface is denoted as H with units of feet. As discussed previously in this report, a value of 35 degrees was selected for the angle of internal friction for the select granular backfill. The wall friction angle was assumed to be zero and the wall face was assumed to be vertical. The unit weight of the select granular backfill (γ) will be determined by the contractor/wall designer based on the actual backfill material to be used.

In order to perform the Mononobe-Okabe (M-O) analyses for the free standing structures, it is necessary to make assumptions regarding the earthquake and associated accelerations. Obviously, a larger earthquake with larger accelerations would impose larger forces on the below grade wall. Published recommendations for the selection of accelerations to be used in pseudo-static analyses such as M-O generally assume the pseudo-static vertical seismic coefficient of acceleration to be zero as was the case in these analyses. However, a number of potential methods to estimate the pseudo-static horizontal seismic coefficient of acceleration are available. For estimating the pseudostatic horizontal seismic coefficient of acceleration, we have used the Elms and Martin (1979) relationship that estimates the pseudo-static horizontal acceleration coefficient as the acceleration coefficient (As) divided by 2; this relationship assumes a maximum outward wall displacement up to (10As) in inches. Based on the previously determined acceleration coefficient and the Elms and Martin (1979) relationship, the pseudo-static horizontal seismic coefficient of acceleration was estimated to be 0.199. The backfill slope angle was estimated to be approximately 5 degrees based on dimensions depicted on the Conceptual Drawing.

Analyses utilizing the M-O equations and the above acceleration data results in a predicted Lateral Dynamic Component Force (LDCF) with units of pounds per linear (horizontal) foot of wall as follows:

$LDCF = (11.3)(\cdot\ H^2)$

The height (H) above the wall base at which the resultant dynamic force acts on the wall becomes greater as earthquake effects increase. Wood (1973) found that the resultant of the dynamic pressure acted approximately at the wall mid-height. We recommend that the point of action of the resultant dynamic force be taken as the wall mid-height (i.e., at a height of H/2 above the wall base). Further, the dynamic force may be assumed to act as a uniformly distributed pressure.

In addition to the dynamic force, the static component of the earth pressure would also act on the wall. The design parameters for determining the static component of the earth pressure are provided in this report.

Specific Design Requirements

The retaining wall shall have a drainage gutter at the top designed to carry surface runoff to either or both ends of the wall. A drainage gutter is typically shown for reference; however, actual details are to be provided in the contractor's wall design plans. If a Concrete Cantilever Wall is used, the wall designer must provide for a drainage layer behind the wall stem with adequate drainage provided via weep holes.

The upper fine-grained soils encountered at this site are expected to be sensitive to disturbances caused by construction traffic and to changes in moisture content. During wet weather periods, increases in the moisture content of the soil can cause significant reduction in the soil strength and support capabilities. In addition, soils which become wet may be slow to dry and thus significantly retard the progress of grading and compaction activities. It will, therefore, be advantageous to perform earthwork, pavement and foundation construction activities during dry weather.

Water should not be allowed to collect in the foundation excavations or on prepared subgrades for pavements during construction. Positive site drainage should be maintained throughout construction activities. Undercut or excavated areas should be sloped toward one corner to facilitate removal of any collected rainwater, groundwater, or surface runoff. The site grading plan should be developed to provide rapid drainage of surface water away from pavement areas and to inhibit infiltration of surface water beneath the pavements. The grades should be sloped away from the pavement areas.

SEALED BY

STATE OF TENNESSEE
DEPARTMENT OF TRANSPORTATION

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