MATERIALS DIVISION

MEMORANDUM

GENERAL SUBJECT: **Soil Slope Stability Requirements**	**NUMBER:** **MD 340-10**
SPECIFIC SUBJECT: Materials Manual of Instructions Chapter III: Addition of Section for Soil Slope and Embankment Design, Analysis, and Evaluation	**DATE: August 2, 2010**
DIRECTED TO: **District Materials Engineers**	**SIGNATURE:** **Charles A. Babish, PE** *Signature on original copy of memorandum*

This Memorandum notifies the users of the Materials Division Manual of Instructions that a new section, 302.04, of Chapter III has been added.

The purpose of the change is to formally incorporate into VDOT policy requirements for soil slope stability design, analysis, and evaluation, including providing requirements and guidance on reinforced slopes and LRFD methodology.

302.04 Soil Slope and Embankment Design, Analysis, and Evaluation

Design stable soil slopes (cut slopes and embankment slopes) and evaluate stability for interim construction stages, for the end of construction condition, and for design-life conditions. The maximum slope ratio to be used for cut slopes or roadway embankment fill slopes shall not be steeper than 2H:1V, unless otherwise approved by the District Materials Engineer. The stability of rock slopes and rock cuts shall also be evaluated on VDOT projects, however, these topics will be addressed in a separate section.

Any exception to the requirements of this section must be approved in writing by the VDOT District Materials Engineer on a project-specific or case-by-case basis.

The factors of safety in Table 1 below are to be used with limit equilibrium methods of analysis for representative sections of slope greater than 15 feet in height or for critical slopes or slopes in problem soils as defined below. The factors of safety are valid for subsurface investigations performed in accordance with Chapter III of the Materials Division's Manual of Instructions or for

site specific investigation plans approved by the District Materials Engineer. Approval of site specific investigation plans with reduced boring frequency may require higher factors of safety.

Circular failure surfaces shall be analyzed by methods such as the Modified Bishop, simplified Janbu or Spencer methods. In addition, a block analysis shall be performed to verify the minimum factor of safety.

Table 1: Minimum Factors of Safety (Factored Resistances) for Slopes

Slope soil parameters based on:	Factor of Safety	
	Critical Slope[1]	Non-Critical Slope
Site specific in-situ or laboratory strength tests of soils[2]	1.5	1.3
No site specific in-situ or laboratory strength tests of soils[2]	N/A[3]	1.5

Notes:
1. A critical slope is defined as any greater than 25 feet in height, affects or supports a structure, impounds water or whose failure would result in significant cost for repair~~,~~ or damage to private property.
2. Site specific in-situ tests include both ground water measurements and SPT but may also include CPT or DMT.
3. Parameters for critical slopes must be based on site-specific in-situ or laboratory strength tests.

Problem soils for slope stability are very soft soils, very loose soils, and fissured or heavily over-consolidated soils. (Fissured or heavily over-consolidated soils include the Potomac Formation and Calvert Formation silt and clay soils.) Problem soils shall be analyzed for short- and long-term stability using appropriate strength parameters determined from laboratory shear testing. For fissured or heavily over-consolidated soils this shall include residual strength parameters for long-term stability analysis. Residual strength parameters shall be determined by drained direct shear tests using sufficient stress reversals to obtain large strains as discussed in the Corps of Engineers laboratory testing procedures EM-1110-2-1906. Many reversals are required to reach residual strengths and some references suggest using a pre-split sample (Ref. Engineering properties of Clay Shales, Report No. 1 by W. Haley and B.N. MacIver).

When slope stability analyses are conducted, the following geotechnical and geological conditions must also be addressed:

- Slip planes occurring between heterogeneous soil strata.
- Karst geology and the short- and long-term effects of voids and sinkholes encountered and their maintenance and repair.
- Moisture effects on strength and properties of micaceous soils.
- Settlement of embankments.
- Seasonal change of groundwater table.
- Tension cracks (if present) at head of slope.

Construction plans shall specify use of soil types consistent with the parameters used in slope analyses.

Locations where ground water seepage in the finished cut slope is anticipated shall be determined and slope surface treatments to stabilize the conditions shall be provided. This is in addition to treatments needed to prevent scour and undermining of both cut and fill slopes within the drainage areas of the site.

VDOT projects contracted as Public-Private Transportation Act (PPTA) or Design-Build (DB) projects shall also include provisions for slope stability reliability assessments.

All data, assumptions, and calculations (hand calculations and electronic files if warranted, including software input and output files) shall be included in reports submitted for review.

302.04 (a) Reinforced Slope Requirements

Approval for use of reinforced slopes shall be obtained from the VDOT District Materials Engineer. Typically, the District Materials Engineer will work with the District Maintenance Engineer on this approval due to long-term maintenance considerations of reinforced slopes. Approval of over-steepened reinforced slopes will only be granted when it has been reasonably shown that there are no other feasible alternatives to 2H:1V slopes at the sole discretion of the District Materials Engineer.

In addition to slope requirements of this Section 302.04, reinforced slopes shall be designed or analyzed in regard to the following potential failure mechanisms:

- External stability and settlment:
    - Overall bearing capacity
    - Local bearing failure (lateral squeeze or mud wave)
    - Heave of adjacent ground (consider as a deep-seated failure)
    - Settlement
- Internal stability:
    - Internal shear stability, long-term
    - Lateral spreading (sliding)
- Compound failure

In all cases, the design and analysis guidance and minimum factors of safety specified in *FHWA Publication Nos. NHI-10-024 and NHI-10-025 (also known as GEC 11), dated November 2009, Design and Construction of Mechanically Stabilized Earth Walls and Reinforced Soil Slopes, for NHI Course Nos. 132042 and 132043.*

302.04 (b) LRFD Requirements

On projects for which the AASHTO LRFD Bridge Design Specifications are to be used for structures, slope design or analysis shall be made using the Load and Resistance Factor Design (LRFD) methodology (Section 11.6.2.3 of the LRFD code). This methodology does not differ in any material way from traditional slope stability analysis; LRFD is at this point in time a change in terminology as it applies to slope stability analysis.

The following criteria will apply to LRFD methodology:

- Rather than reporting the term “factor of safety”, the term “performance ratio” may be reported to clearly signify an LRFD job. A performance ratio is the sum of factored resistances divided by factored driving forces for a given limit state. The term is taken from the way the ABLRFD program reports output. ABLRFD is the computer program the Virginia DOT Structure and Bridge Division uses for LRFD design of bridge abutments.
- External loads on slopes (for example, due to a bridge abutment spread footing) shall be designed using the Service I Load Combination of these loads, as given in Section 3.4.1 of the AASHTO LRFD Bridge Design Specifications. These loads are to be incorporated into limit

equilibrium analyses or numerical analyses as they have traditionally been analyzed; there are to be no further factors applied to the loads and no further resistance factors applied to any soil or berm resisting mechanisms in the slope stability analysis (meaning resistance factors are equal to 1.0).

- Slope reinforcing (such as geosynthetics, anchors, piling, caissons, etc.) shall be incorporated into slope stability analysis using traditional allowable stress design methods.
- As the LRFD Bridge Design Specifications currently make no mention of slope external stability and settlement considerations, these shall continue to be evaluated for reinforced slopes as described in 302.04 (a) above using allowable stress methods with factors of safety. Rather than reporting the term "factor of safety", the term "performance ratio" may be reported to clearly signify an LRFD job.

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