THE UNIVERSITY OF UTAH

Department of Civil &
Environmental Engineering
110 Central Campus Drive
Salt Lake City, Utah 84112

January 22nd, 2015

Subject: Application of Caltrans mechanically stabliized earth wall design requirements to light-weight cellular concrete backfill

The following summarizes CalTrans design requirements and methodogies and their application to a light-weight cellular concrete (LCC) backfill poured within mechanically stabilized earth (MSE) wall system.

Design Criteria

Bridge Design Specifications (2004), Section 5 Retaining Walls

5.2.2.3 Overall Stability

"As part of the design, the overall stability of the retaining wall, retained slope and foundation soil or rock shall be evaluated for all walls using limiting equilibrium methods of analysis. A minimum factor of safety of 1.3 shall be used for the design of walls for static loads, except that a minimum factor of safety of 1.5 shall be used for the design of walls which support bridge abutments, buildings, critical utilities, or other installations for which there is a low tolerance for failure. A minimum factor of safety of 1.0 shall be used for the design of walls for seismic loads."

"…Seismic forces applied to the mass of the slope shall be based on a horizontal seismic acceleration coefficient, kh, equal to one-third of, A, the expected peak acceleration produced by the Maximum Credible Earthquake on bedrock at the site as defined in the Caltrans Seismic Hazard Map. Generally the vertical seismic coefficient, kv, is considered to equal zero."

"…For seismic loads, if it is determined that the factor of safety for the slope is less than 1.0 using one-third of the peak bedrock acceleration, procedures for estimating earthquake induced deformations such as the Newmarks' Method may be used provided that the retaining wall and any supported structure can tolerate the resulting deformations."

Comments

It is recommended that the LCC wall be evaluted for overall stability (i.e., global stability) using the design requirements given above (Sections 5.2.2.3 and 5.9.2). This can be done using limit equilibrium methods, or using numerical analysis based on limit equilibrium (LE) methods, or more advanced constitutive modeling (finite element (FE) or finite difference (FD) methods). For these analyses, it is recommended that results of direct shear tests be used to define the Mohr-Coulumb failure envelope. The parmeters for these evaluations should include the drained cohesion intercept, c', and drained friction angle, ', for the LCC material, as obtained from testing at an appropriate range of applied normal stress. In addition, if LE, FE or FD methods are used, the tensile capacity of the MSE reinforced zone should be accounted for in the global stability analyses using either implicit or explicit modeling of the reinforcement.

It is recommended that inextensible reinforecement be considered for LCC systems, and that 75 percent of the ultimate pullout capacity be used in the globals stability evaluations (C5.5.5.7.2a). The requirements for the reinforcement should be made using the guidance given in the following section.

5.9.2 External Stability

"The length of soil reinforcement for MSE walls shall be determined to ensure stability against failure modes by satisfying the following stability criteria:

- *Sliding – Factor of safety, $FS_{SL} \geq 1.5$*
- *Overturning – factor of safety, $FS_{OT} \geq 2.0$, and*
- *Maximum eccentricity of the resultant force, L, acting on the base of wall, emax ≤ 6*
- *Bearing capacity - factor of safety, $FS \geq 2.0$.*

Stability determinations shall be made assuming the reinforced soil mass and facing to be a coherent gravity mass. The design lateral earth pressure acting on the pressure surface at the end of the soil reinforcement shall be determined in accordance with Article 5.5.5.8 using the friction angle and unit weight of the retained soil. For battered walls with an inclined pressure surface, Coulomb's theory may be used assuming the wall friction angle, d , equals, b , or B. For standardized wall designs a friction angle equal to 34 degrees may be assumed for the retained soil and 30 degrees for the foundation soil.

In developing the total design lateral pressures acting on the pressure surface, the lateral pressure due to surcharge loads shall be added to the design lateral earth pressure. Refer to Article 5.5.5.10 for the determination of design lateral pressures due to surcharge loads.

When groundwater levels may exist within the reinforced soil mass and/or retained soil, they shall be considered in stability determinations.

The resistance due to passive lateral earth pressure in front of an MSE wall shall be neglected in sliding and overturning stability determinations.

For external stability determinations the weight and dimensions of the facing elements are typically ignored, although they may be included.

For external stability determinations traffic surcharge loads shall be considered to act beyond the end of the reinforced soil mass."

Comments

Unconfined compression testing and direct shear testing show that the LCC material exhibits a considerable amount of cohesion, at least when compared with most types of soils (see preliminary test results by Dr. Tiwari – Attachment 1). In addition, these results show that the cohesion of the material is greater in uniaxial compression (unconfined compression) than in direct shear by about a factor of 2, suggesting considerable strength anisotrophy.

However, current Caltrans design methods have no suggested method for accounting significant cohesion and anisotrophy in the design of the MSE wall system. They are primary based on methods developed for granular material where cohesion is neglected.

The significant cohesion manifested by LCC will produce a free-standing embankment in many cases, which will not exert significant lateral earthpressure against the retaining system. Notwithstanding, it is also recognized that significant long-term cohesion in the LCC backfill cannot be guaranteed during the design life of the system due to the potential for degradation from environmental factors and other loading conditions. Hence, it is recommended Rankine active earth pressure theory be used to determine the lateral earthpressure with the MSE wall system without the presence of cohesion. For this, it is recommended that the results of the direct simple shear tests be used (Attachment 1). (These tests show a drained friction angle of approximately 35 degrees, and a cohesion intercept that is reasonably low.) Note also that Rankine Theory should only be used for cases where this is no significant backslope.

In addition, as per Caltrans requirements, the attached figure should be used to assess the internal stability of the LCC backfill.

Lastly, it is recommend that project-specific pullout/interface tests be performed to determine the design properties for the reinforcement placed in the LCC resistance zone. These tests should be done using the type of reinforcement and density and mix of LCC planned for the specific project.

Respectfully,

Steven Bartlett

Steven Bartlett, Ph.D., P.E.
Associate Professor

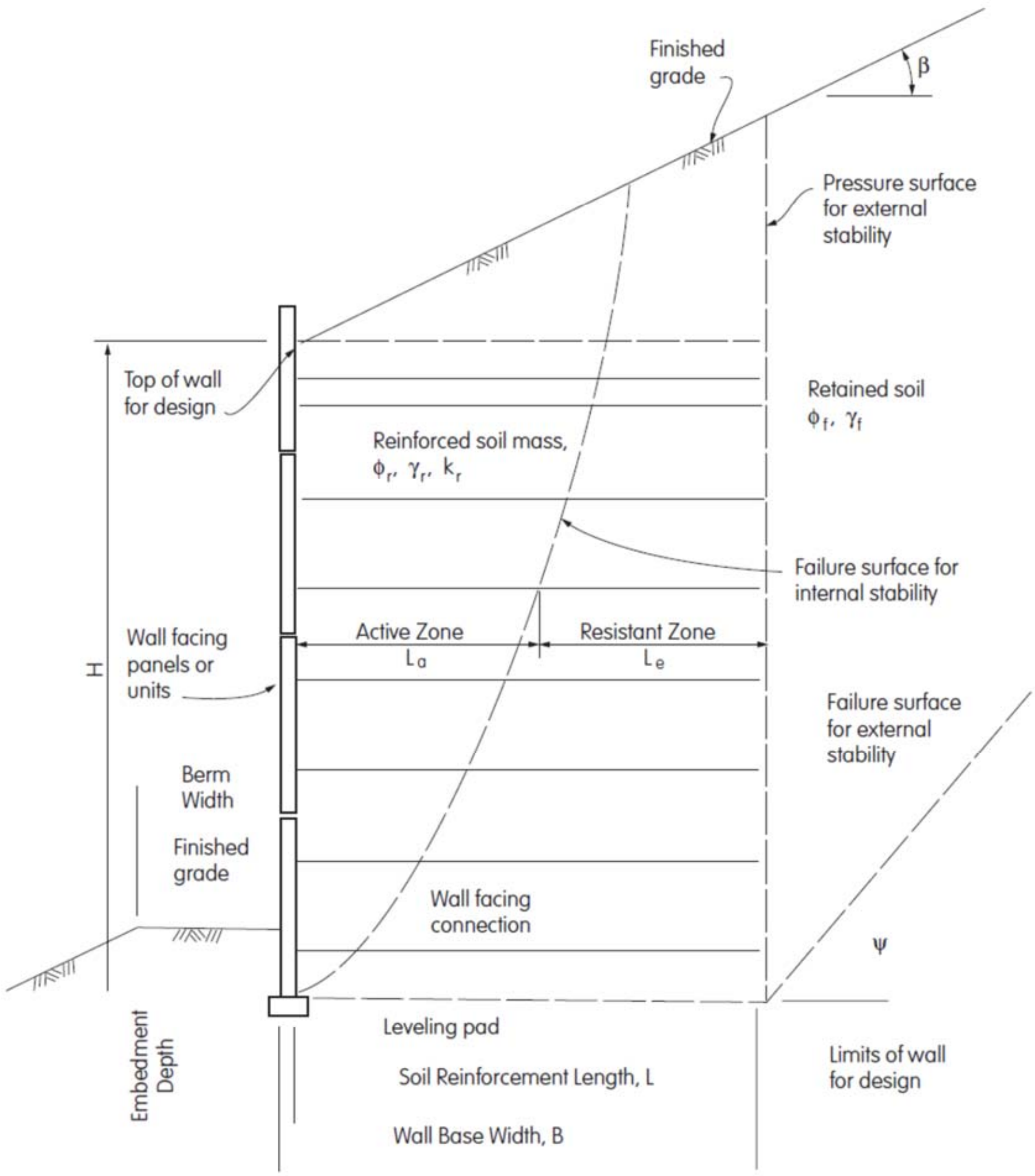

Figure 5.9.1-1 MSE Wall Element Dimensions Needed for Design.