Characterization of Frictional Interference in Closely-spaced Reinforcements in MSE Walls

Armin W. Stuedlein, PhD, PE, Principal Investigator, James J. Walters, and Andrew W. Strahler
School of Civil and Construction Engineering, Oregon State University, Corvallis, OR
This material was also supported by the National Science Foundation under Grant No. CMMI 1109033.

PROBLEM STATEMENT

The use of reinforced earth in the United States began in 1972; since then, Mechanically Stabilized Earth (MSE) walls have grown in popularity, and can be found along nearly every state and interstate highway corridor. Due to their inherent flexibility, MSE walls are being constructed to greater heights, in non-linear geometries, with multiple tiers and with very tight reinforcement spacing. For example, the four-tier West MSE wall at Sea-Tac International Airport (STIA see Fig. 1) was recently constructed to 46 m height, and is now the tallest wall in the Western Hemisphere (Stuedlein et al. 2010a). Tall walls (i.e., greater than 15 m in height) will proliferate due to increasing urbanization, right-of-way issues, and wetland mitigation; in other words, they offer a sustainable alternative to conventional grade separation, due to reduced mining and hauling of earth materials and reduced footprint. However, our understanding of the working stress behavior, including reinforcement strains and displacements, of tall, single and multi-tier walls is unsatisfactory. The research proposed herein aims to address one of several knowledge gaps in the understanding of tall MSE wall behavior: prediction of reinforcement loads impacted by frictional interference of closely-spaced reinforcements associated with tall walls and/or walls in seismically active regions.

EXPERIMENTAL PROGRAM & RESULTS

In order to determine whether or not frictional interference contributes to increased loads in MSE walls, the frictional behavior of closely-spaced reinforcement strips must be compared to the frictional behavior of single reinforcement strips. The reinforcement strips used in this study were galvanized ribbed steel strips 50 mm (2 in.) wide by 6 mm (0.24 in.) thick, as shown in Figure 2. In order to properly evaluate tensile stress-strain behavior of these reinforcement strips, tension testing was performed on the actual steel strips used in the 3rd Runway Project, resulting in $E = 208$ GPa and $f_y = 526$ MPa.

The fill material used in this study was a well-graded sandy gravel, identical to the fill material used in the 3rd Runway Project at Sea-Tac International Airport. A comprehensive large-diameter triaxial test program was undertaken to determine the stiffness and strength of the fill material for comparison to the pullout test results. Figure 3a, 3b, and 3c shows typical stress-strain, principal stress ratio-strain, and volumetric strain-strain curves for the densely compacted fill material, respectively, whereas Figure 3d shows the variation of the friction angle with effective confining pressure for a range in relative densities of the fill material.

Multi-strip pullout tests were performed in a large, 4 m$^3$ soil box (Fig. 4c – 4f) to evaluate the effect of spacing on frictional interference, and therefore load amplification, in reinforcement strips. A comparison of nine reinforcement strips spaced at 152 mm (6 in.) and tested at 100 kPa overburden pressure is shown in Fig. 6; here, it is observed that strips that are confined (strips 4 – 6) exhibit greater loads than those that are just partially confined. Additionally, the center strip (#5) is shown to exhibit 25% greater load than the single strip at the same overburden pressure (Fig. 5a). Load multipliers (Fig. 7) can be used to indicate the increase in load resulting from spacing effects, and are defined as the ratio of the load in a middle strip divided by the mean external strip loads in a row or column. The effect of horizontal spacing on load amplification is relatively constant for the spacings investigated, however, the load amplification is sensitive to the vertical spacing. Spacing greater than 300 mm (12 in.) appear to produce no load amplification. These findings will serve to inform future MSE wall designs.