



INDOT Research

TECHNICAL *Summary*

Technology Transfer and Project Implementation Information

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Design of MSE Walls for Fully Saturated Conditions

Introduction

Over the past three decades, Mechanically Stabilized Earth (MSE) retaining walls have been increasingly used as design alternatives to traditional reinforced concrete retaining walls for supporting earth fills in civil infrastructure projects. MSE walls can retain earth fills of significant height and sustain surface applied loads at lower cost than reinforced concrete walls. Because they are flexible and mechanically redundant structures, MSE walls are particularly suitable for difficult foundation soil conditions where differential settlements are anticipated. In general, MSE retaining walls consist of structural fill reinforced with tensile-resistant inclusions that are connected to facing elements. The internal stability of the reinforced soil structure is provided by mechanical interactions of its three components, i.e. fill material, reinforcement, and facing.

MSE walls are much more economical than traditional cast-in-place concrete walls. Current design of MSE walls for drained conditions is based on limit state analyses in which the ultimate strength of the soil and the pullout capacity of the reinforcement are incorporated. This approach has been satisfactorily used for a large number of walls. However for fully saturated conditions there are no clear guidelines for the design of MSE walls.

INDOT design guidelines contain the following statement: "For fully saturated conditions, site-specific field or laboratory pullout tests shall be performed". Performance of such tests is very time-consuming and expensive. As a result, MSE walls are not specified for many projects.

The stability of MSE walls may be compromised in undrained conditions such as during a heavy rain or during a rapid drawdown. Excess pore pressures in low permeability soils may not dissipate quickly enough, and thus may reduce the effective stresses inside the soil, which in turn may cause a reduction of the shear strength at the interface between the soil and the reinforcement. The study of MSE walls in undrained conditions is needed to determine the behavior of saturated MSE walls where rapid changes in pore pressures are anticipated. For this purpose, a series of laboratory pullout tests are performed under drained and undrained conditions for different soil types ranging from clean sand to 35 % silty sand and for overburden pressures of 30, 100 and 200 kPa. Numerical analyses are also conducted to determine scale and permeability effects for the dissipation of excess pore pressures.

Findings

Results from the experimental and numerical investigation of the drained and undrained pullout capacities of a steel reinforcement embedded into a silty sand soil matrix show that:

(1) Effect of silt: Drained and undrained pullout capacities decrease from clean sand to 5 % silty sand, increase from 5 % to 10 %, and then decrease from 10 % to 15% and 35 %

silty sand. The pullout capacity changes as the internal friction angle of the soil changes because the pullout capacity increases as the internal friction angle of the soil increases.

(2) Effect of overburden pressure: The pullout capacity increases as the overburden pressure increases. Larger displacements are required to reach the maximum pullout

capacity for higher overburden pressures. Higher soil stiffness is observed for higher overburden pressure.

- (3) Effect of drainage: The undrained pullout capacity is always smaller than the drained pullout capacity except for clean sand, which is the same. The ratio of undrained to drained pullout capacity changes with silt content and with overburden pressure. For 100 kPa and 200 kPa overburden pressure the ratio is 1.0 for clean sand, decreases to 0.67~0.69 for 5 % silty sand, 0.77~0.78 for 10 % silt, 0.72~0.73 for 15 % and 0.57~0.59 for 35 % silt. For 30 kPa overburden, the ratio is 1.0 for clean sand, 0.5 for 5 % silt, 0.67 for 10 % silt, 0.78 for 15 % silt and 0.72 for 35 % silt. Drained pullout tests usually show strain hardening, or at least no reduction in pullout load, after

maximum pullout; in contrast, undrained pullout tests are generally strain softening. This is a particularly important finding since it indicates that failure in drained conditions will be progressive while in undrained conditions will be sudden and catastrophic.

- (4) Effect of permeability: The dissipation of pore pressures inside the soil is very rapid for permeabilities larger than 10^{-2} cm/sec. For permeabilities smaller than 10^{-3} cm/sec, dissipation of pore pressures is very slow.
- (5) Effect of scale: For permeabilities smaller than 10^{-3} cm/sec, scale effects are extremely important in that the larger the reinforcement, the longer the time for pore pressures to dissipate.

Implementation

Based on the findings from experiments and numerical analyses, the following is recommended for implementation:

- (1) A small percentage of non-plastic fines in the backfill soil may have positive effects since the fines occupy the void space and decrease the void ratio, thus increasing the internal friction angle. Once the percentage of fines reaches a threshold value the addition of fines is detrimental and the internal friction angle and consequently the pullout capacity decrease. This may be caused by the fines preventing the particles to be in contact with each other, and thus reducing the shear stress required to mobilize the grains. For practical reasons, however, it is not recommended to use granular materials with fines content larger than 5 to 10 % since segregation may become an issue and the material may be sensitive to changes in water content. As a general recommendation the fines should be non-plastic. For each project, the adequacy of a particular granular material as a backfill for a wall that will not experience undrained conditions can be evaluated by running triaxial tests on the material compacted to the required density.

- (2) Granular materials with even a small percentage of fines are not recommended as backfill in walls where undrained conditions may occur. This is because of the large reduction of pullout capacity observed, which can be as much as 50 %. An additional detrimental effect of fines is that they can be washed out of the backfill as the water level behind the wall changes; this may produce internal erosion and damage the wall. However, submerged or partially submerged MSE walls can be safely used if a clean granular backfill is used. Indiana DOT stone # 8 material is appropriate for this situation because of the low percentage of fines and large permeability.
- (3) The findings from this research also show that field tests under drained conditions are not appropriate to evaluate the undrained pullout capacity under undrained conditions. If for a particular project, the undrained pullout capacity of a reinforcement embedded in a soil matrix needs to be evaluated, laboratory tests similar to the ones performed in this research are recommended. As a lower bound, the undrained shear strength of the soil could be used for stability calculations.

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