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Electrical resisitivity of mechancially stablized earth wall backfill

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ABSTRACT

Mechanically stabilized earth (MSE) retaining walls utilized in transportation projects are typically backfilled with coarse aggregate. One of the current testing procedures to select backfill material for construction of MSE walls is the American Association of State Highway and Transportation Officials standard T 288: “Standard Method of Test for Determining Minimum Laboratory Soil Resistivity.” T 288 is designed to test a soil sample's electrical resistivity which correlates to its corrosive potential. The test is run on soil material passing the No. 10 sieve and believed to be inappropriate for coarse aggregate. Therefore, researchers have proposed new methods to measure the electrical resistivity of coarse aggregate samples in the laboratory. There is a need to verify that the proposed methods yield results representative of the in situ conditions; however, no in situ measurement of the electrical resistivity of MSE wall backfill is established. Electrical resistivity tomography (ERT) provides a two-dimensional (2D) profile of the bulk resistivity of backfill material in situ. The objective of this study was to characterize bulk resistivity of in-place MSE wall backfill aggregate using ERT.

Five MSE walls were tested via ERT to determine the bulk resistivity of the backfill. Three of the walls were reinforced with polymeric geogrid, one wall was reinforced with metallic strips, and one wall was a gravity retaining wall with no reinforcement. Variability of the measured resistivity distribution within the backfill may be a result of non-uniform particle sizes, thoroughness of compaction, and the presence of water. A quantitative post processing algorithm was developed to calculate mean bulk resistivity of in-situ backfill. Recommendations of the study were that the ERT data be used to verify proposed testing methods for coarse aggregate that are designed to yield data representative of in situ conditions. A preliminary analysis suggests that ERT may be utilized as construction quality assurance for thoroughness of compaction in MSE construction; however more data are needed at this time.

1. Introduction

Mechanically stabilized earth (MSE) walls are often more economical than conventional concrete retaining walls; therefore, they have become increasingly popular as earth-retaining solutions. Koerner and Koerner (2013) estimated that 150,000 MSE walls have been built worldwide. MSE walls generally consist of three components: vertical facing, leveling pad, and reinforced backfill (Fig. 1). Reinforcement in the backfill significantly increases material strength, consequently allowing MSE walls to be taller than traditional retaining walls. Backfill is typically selected prior to construction based on specific material properties, including its potential to foster a corrosive environment. When metallic reinforcing elements are used, corrosion of the reinforcement can result in loss of thickness, stiffness, and strength. In extreme cases, reinforcement corrosion can lead to failure of the MSE-wall system (Armour et al., 2004; Thornley et al., 2010). Although polymeric reinforcement, such as geosynthetic, is not susceptible to corrosion, typically all backfill material must satisfy corrosion criteria in transportation structures.

Corrosion is metal deterioration due to electrochemical reactions within the environment. Natural electric current flows when a voltage potential difference between two electrically connected points is present (Cicek, 2014). These points may be two metal objects or two points on the same metal object connected by an electrolyte, such as water (Elias et al., 2009). The area into which the current flows becomes corroded. In MSE-wall backfill, corrosion can occur over a large area, such as the entire surface of a piece of reinforcement, or in localized areas, causing small indentations called pits (Elias et al., 2009).

Assessment of a soil's corrosive potential requires accurate evaluation of pH, electrical resistivity, and sulfate and chloride concentrations of fluids in contact with the soil. The American Association of State Highway and Transportation Officials (AASHTO), the American Society of Testing and Materials (ASTM), the Federal Highway Administration (FHWA), state departments of transportation (DOTs), and local organizations have created guidelines, standards, testing procedures, and construction quality assurance (CQA) protocols for earth-retaining structure backfill materials (AASHTO, 2013; ASTM, 2012; Elias et al., 2009). This research focused on the AASHTO standard for measuring

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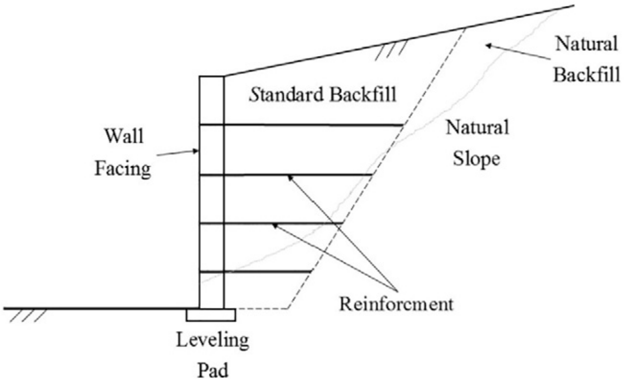

Fig. 1. MSE wall schematic.

soil resistivity (T 288). The FHWA typically recommends that DOTs use T 288 ("Standard Method of Test for Determining Minimum Laboratory Soil Resistivity") to evaluate electrical resistivity of select backfill for MSE walls. In addition, pH, organic content, and chloride and sulfate concentrations are recommended to assess a soil's corrosive potential, but they are infrequently used and are beyond the scope of this study.

The FHWA has established qualitative levels of corrosiveness with measured ranges of electrical resistivity, as shown in Table 1. Soils with high electrical resistivity reduce the likelihood of current flow within a system, thereby reducing the potential for reinforcement corrosion (King, 1978). Select backfills identified as moderate to mildly corrosive are generally acceptable for MSE walls.

In the T 288 method, only material passing the No. 10 (2.00 mm) sieve is utilized. The dry material is mixed with 150 ml of distilled water and compacted into a 688 cm^3 box. Soil resistivity is calculated by multiplying the measured minimum resistance of the soil-water mixture by the volume of the soil box. Additional water is added to the soil sample until a minimum resistance is measured up to saturation of the sample. T 288 is typically reported in Ohm centimeters (Ω cm) though findings herein are shown as Ohm meters (Ω m), the units of electrical resistivity tomography (ERT). The coarse aggregate (15–25 mm nominal diameter) used for MSE walls often contains only a small percentage of material that passes the No. 10 sieve. T 288 specifically states that "when less than five percent of a material passes the No. 10, this test method may not be indicative of the corrosion potential of the material" (AASHTO, 2013). Thapalia et al. (2011) also found that the material that passes the No. 10 is typically not representative of the corrosive nature of the aggregate, potentially leading to unnecessary rejection of the material. However, T 288 is still the most common criterion for selecting aggregate backfill. There is a need for a method to determine the corrosive potential of coarse aggregate materials.

The objective of this research was to measure the electrical resistivity of MSE wall backfill in situ. Researchers have identified that T 288 is not representative of in situ backfill conditions, particularly when aggregates are utilized. Therefore, researchers have proposed alternative methods to replace T 288 for measuring the minimum resistivity of aggregate backfill in the laboratory (Brady et al., 2016; Yzenas, 2014; Thapalia et al., 2011). To date, no research has measured the actual resistivity of aggregate backfill in situ to validate proposed methods to replace T 288. As such, this study determined the bulk electrical resistivity of aggregate backfill using ERT during construction of five MSE walls. ERT is a near-surface geophysical method that provides a two-dimensional (2D) profile of the bulk resistivity distribution of various materials in the subsurface. ERT can be used to determine geology (Carbonel et al., 2015; Froese et al., 2005), conduct hydrogeological investigations (Koehn et al., in review; Pellerin, 2002), and detect or map contaminant plumes (Vaudelet et al., 2011; Kaya and Fang, 1997).

ERT is becoming an increasingly popular tool in civil engineering to nondestructively image large areas of the subsurface to map between boreholes (Groves et al., 2011; Wisen et al., 2005; Hiltunen and Roth, 2003), monitor the water content of soils (Zhou et al., 2001), identify unknown structures such as bridge foundations (Tucker et al., 2015; Arjwech et al., 2013; Hossain et al., 2011), and map landfills (Bernstone et al., 2000). There is limited research on the use of ERT for earth retaining structures (Adkins and Rutkowski, 1998). Typically earth retaining structures, such as MSE walls, can only be monitored by visual inspection such as noting displacement of the vertical facing or settlement at the top of the backfill. ERT can provide information regarding the internal structure of retaining walls, both during construction for CQA and as a nondestructive monitoring method. Nondestructive verification of detrimental conditions, such as hydrostatic backpressure, would be a cost effective solution to evaluate the risk of failure and identify remediation strategies. This paper presents one novel application for ERT on earth retaining structures; to determine the electrical resistivity of aggregate backfill in situ to furnish representative values for proposed CQA methods. Following this introduction, are a description of experimental test sites and test methods, study results, and discussion of the findings. Concluding remarks and future work are provided in the final section.

2. Experimental sites

Five earth-retaining structures selected by the Kansas Department of Transportation (KDOT) were tested in this study. Three of the structures were reinforced with geogrid (a geosynthetic material), one structure was reinforced with metallic strips, and one structure was an unreinforced gravity wall, as summarized in Table 2. With the exception of Wall 4, the laboratory tested select backfill samples for all structures was aggregate, with more than 50% of the sample material retained on the No. 4 sieve (4.76 mm). The sample backfill of Wall 4 was a sand with 0% retained on the No. 4 and 99.7% of the sample material retained on the No. 200 (2 μm). Although only the wall with metallic reinforcement was susceptible to corrosion, all backfill was tested for corrosion potential prior to selection according to FHWA recommendations. ERT surveys were conducted during breaks in construction or when construction occurred in another area on site. While it is not necessary to test during construction to obtain the bulk measurement of resistivity of MSE wall backfill, only one wall could be tested once construction was complete. The remaining structures were covered with erosion control products or pavement that could not be cored following construction as specified by the KDOT.

This study was conducted in concert with another to recommend alternative laboratory procedures to measure the corrosion potential of aggregate backfill (Brady et al., 2016). The results of this study were used to validate that the proposed testing methodology yielded results

Table 1
Electrical resistivity ranges for corrosion (adapted from Elias et al., 2009).

Corrosiveness	Electrical resistivity (Ω m)
Extremely	Less than 7
Corrosive	7 to 20
Moderate	20 to 50
Mildly	50 to 100
None	Greater than 100

Table 2
Attributes of MSE walls.

Wall	Reinforcement	Height (m)	Length (m)	Material	T 288 (Ω m)
Wall 1	Geogrid	2.0–7.0	76.2	Limestone	38.08
Wall 2	Geogrid	1.5–11.0	353.6	Limestone	38.08
Wall 3	Geogrid	0.8–1.8	118.0	Not provided	
Wall 4	Metal	1.4–7.0	20.0	Limestone	60.36
Wall 5	None	0.0–6.8	92.1	Limestone	38.95