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EXTENDED ABSTRACT

The effect of encapsulation in sand layer and application of end-bend on pullout resistance enhancement of polymeric strap in clay

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1. Introduction

In recent decades, reinforced soil retaining walls have gained popularity due to their ease of construction and low costs. Utilizing polymeric straps for soil reinforcement provides a straightforward and economical way to enhance the strength and deformation characteristics of retaining earth walls. However, these polymeric straps lack adequate pullout resistance, owing to the absence of transverse members. To address this issue, a U-shaped end-bend can be added to the strap, which creates a surface that enhances passive resistance.

Although construction codes (Berg et al. 2009a, Berg et al. 2009b, AASHTO 2010, NCMA 2010) generally emphasize the use of high-quality granular materials as backfills for reinforced soil retaining walls, many construction projects are characterized by local soils that consist of marginal cohesive materials, making them unsuitable for backfills. A promising solution to reduce project costs in reinforced wall construction is the sandwich method (Sridharan et al. 1991, Abdi and Zandieh 2014, Malek Ghasemi et al. 2024), which involves encasing the reinforcement in a thin layer of granular soil within the backfill. This technique not only improves the pullout resistance of the reinforcement but also allows the enclosed layer to serve as a drainage system.

This research investigates the pullout behavior of straps with both direct and U-shaped ends in sand and clay backfills through a series of large-scale pullout tests. Additionally, the impact of the sandwich method on enhancing the pullout resistance of U-shaped polymeric straps is examined.

2. Testing Apparatus and Material Properties

Several large-scale pullout tests were conducted on reinforced soil specimens. The pullout test apparatus, designed in accordance with ASTM D6706, featured a rigid steel box measuring 1200 × 600 × 600 mm. It was equipped with a rubber air bag on the upper surface of the soil to provide uniform and constant normal surcharge pressure (σ_v). Inside the box, a clamp system was installed to secure the strap, while a motor drive with an 80-mm stroke was used to apply the monotonic pullout force to the reinforcement. A load cell, with capacity of 50 kN and precision of 0.5%, measured the applied pullout force. Additionally, a Linear Variable Differential Transformer (LVDT) was placed at the front of the box frame to monitor clamp displacement. An automatic closed-loop servo-controlled system was employed to measure, control, and record both loading and displacement.

Reinforced soil specimens were prepared in the pullout test apparatus, incorporating polymeric straps as reinforcement and sand/clay as the surrounding soil. The polymeric straps were arranged in two configurations: Direct Polymeric Strap (DPS) arrangement and U-shaped Polymeric Strap (UPS) arrangement (see Fig. 1). The clay used in this study is CL soil, compacted to $0.9\rho_{dmax}$ at optimum water content (w_{opt}). The sand employed is angular sand, characterized by a wide grain size distribution. Several reinforced specimens

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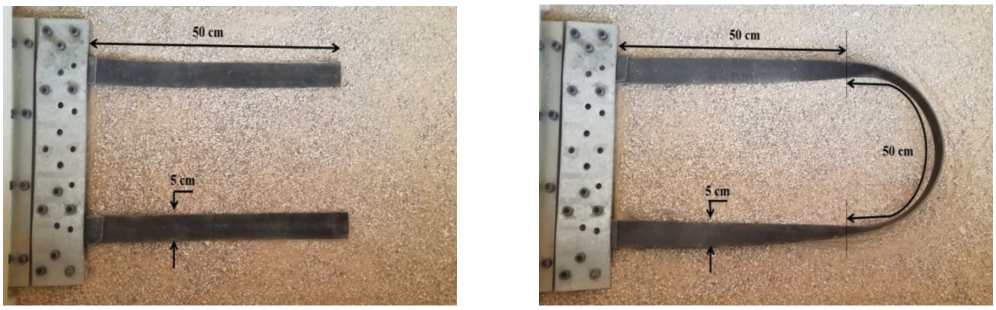
were tested, including those with uniform clay surrounding both DPS and UPS, uniform sand surrounding both DPS and UPS, and a sandwich method where a thin layer of sand encloses the UPS while both are surrounded by clay.



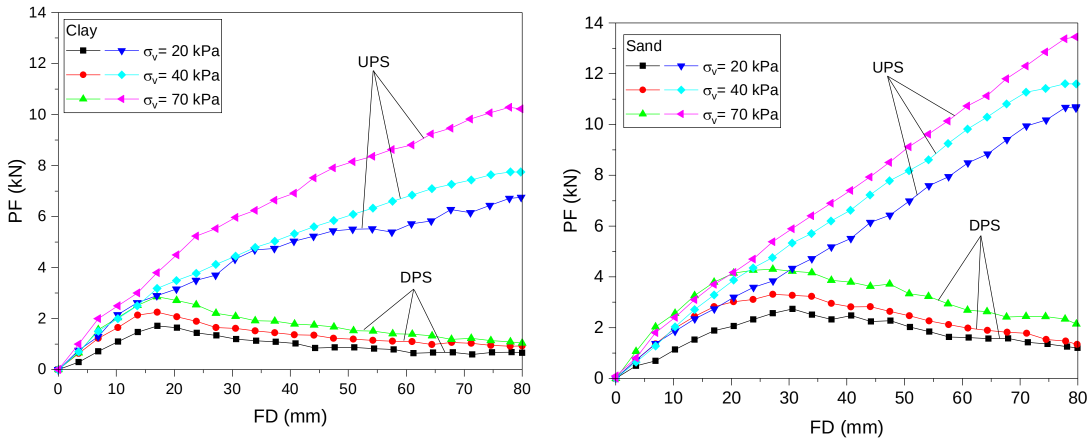
(a) (b)

Fig. 1. Strap configuration (a) DPS (b) UPS

3. Results and discussion

3.1. Effect of U-shaped ending on the pullout resistance of the strap

According to Fig. 2, the variations of pullout force (PF) versus frontal displacement (FD) exhibit a peak value for the DPS reinforcements, while the UPS reinforcements show a consistent ascending trend. The peak observed in DPS arrangement stems from the fact that the only factor contributing to pullout resistance is the friction between the strap and the surrounding soil. In contrast, the UPS benefits from both friction resistance and additional passive resistance in front of the U-shaped section. Consequently, in DPS, once the peak friction angle is reached, a softening behavior is evident, whereas in UPS, the pullout force continues to rise without interruption. The increase in the maximum pullout resistance of UPS compared to DPS is influenced by the surcharge pressure and the type of soil surrounding the strap. On average, the maximum pullout resistance of UPS is approximately 3 times greater than that of DPS.



(a) (b)

Fig. 2. Variation of pullout force of DPS and UPS in uniform (a) clay and (b) sand with respect to frontal displacement

3.2. Effect of sandwich technique on the pullout resistance of UPS

Sand layers with thicknesses of (t=) 20, 50, 100, and 150 mm were utilized in the sandwich technique. As shown in Fig. 3, the pullout resistance (i.e., PF_{max}) of UPS in sandwich system increased as the thickness of the sand layer augmented. However, for each applied surcharge pressure, there exists a thickness (t) of sand layer beyond which the rate of increase in pullout resistance no longer rises with additional increase in sand layer thickness. This threshold is 20 mm for the surcharge pressure (σ_v) of 20 kPa, and 50 mm for surcharge pressures of 40 and 70 kPa. On average, the maximum pullout force (PF_{max}) of UPS in sandwich system is approximately 5 times greater than that of DPS in clay soil.

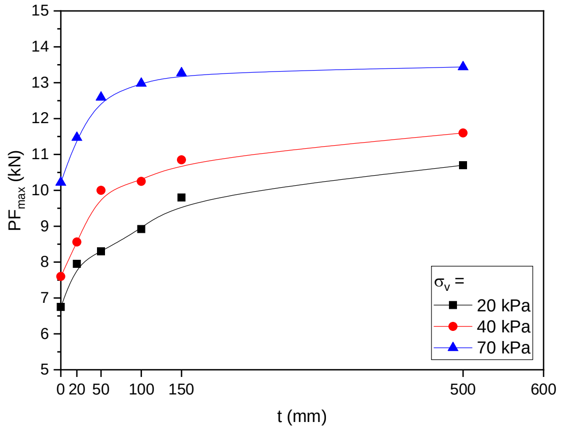


Fig. 3. Variation of pullout strength with respect to the thickness of sand layer in sandwich method

4. Conclusions

Large-scale pullout tests were conducted on reinforced soil specimens that were reconstituted by embedding either a direct polymeric strap or a U-shaped polymeric strap within uniform clay, uniform sand, or a sandwich system (i.e., layer of sand surrounding the strap). The main conclusions drawn from the experimental observations are as follows:

1- Improvising a U-shaped section at the end of a strap significantly enhances the pullout capacity in both sand and clay, resulting in approximately 250% increase of pullout force.

2-Using sand around the direct polymeric strap and U-shaped polymeric strap increases the pullout capacity of the strap to approximately 160% of its capacity in clay.

3- The simultaneous use of the sandwich method and the U-shaped system increases the pullout capacity of a strap in clay by approximately 400%.

5. References

AASHTO, "LRFD Bridge Design Specifications", third ed. AASHTO, Washington, DC, 2010.

Abdi M.R., Zandieh A.R., "Experimental and numerical analysis of large scale pull out tests conducted on clays reinforced with geogrids encapsulated with coarse material", Geotextiles and Geomembranes, 2014, 42, 5, 494–504. https://doi.org/10.1016/j.geotexmem.2014.07.008.

ASTM, "Standard Test Method for Measuring Geosynthetic Pullout Resistance in Soil", ASTM, U.S.A. ASTM Designation: D6706-01, 2001.

Berg R.R., Christopher B.R., Samtani N.C., "Design of Mechanically Stabilized Earth Walls and Reinforced Soil Slopes – Volume I", FHWA. National Highway Institute Federal Highway Administration U.S. Department of Transportation, Washington, D.C, 2009a.

Berg R.R., Christopher B.R., Samtani N.C., "Design of Mechanically Stabilized Earth Walls and Reinforced Soil Slopes – Volume II", FHWA. National Highway Institute Federal Highway Administration U.S. Department of Transportation, Washington, D.C, 2009b.

Malek Ghasemi S., Binesh S.M., Tabatabaie Shourijeh P., "Improving clay-geogrid interaction: Enhancing pullout resistance with recycled concrete aggregate encapsulation", Geotextiles and Geomembranes, 2024, 52, 6, 1145-1160, https://doi.org/10.1016/j.geotexmem.2024.07.010.

NCMA, "Design Manual for Segmental Retaining Walls", third ed. National Concrete Masonry Association, VA, USA, 2010.

Sridharan A., Murthy B.S., Bindumadhava, Revanasiddappa K., "Technique for using fine-grained soil in reinforced earth", Journal of geotechnical engineering (ASCE), 1991, 117, 8, 1174–1190, https://doi.org/10.1061/(ASCE)0733- 9410(1991)117:8(1174).