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Investigating Soil-Geogrid Interaction: Insights from Long-Term Pullout Tests

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Abstract. The study investigates the impact of soil confinement and interaction on the long-term tensile response of geosynthetics. To achieve this goal, a novel large-scale laboratory apparatus was developed; it allows us to investigate the pullout behaviour of geogrids embedded in a compacted granular soil and subjected to sustained tensile loadings. Comparisons between confined tensile strains and strains obtained from in-air tensile creep tests suggest that the creep reduction factor used in the limit state design approach may be conservative. Moreover, another key outcome of the research is the proposal of a procedure for determining the interface parameter necessary to design the length of the reinforcement. This procedure takes into account the viscous effects of polymeric materials under serviceability conditions during the design working life of the geosynthetic-reinforced soil structure.

1 Introduction

The durability of geosynthetics influences the design of civil and environmental engineering works. Regarding tensile strength, the value obtained from standard tensile tests conducted in-air on wide-width specimens (UNI EN ISO 10319, 2015; ASTM D6637, 2015) must be reduced using factors that account for the potential mechanical damage during installation, chemical and environmental degradation, and the effects related to the viscous nature of the polymers. The reduction factor related to the viscous properties of geosynthetics (i.e., creep factor) is generally the most significant, especially for polyolefins.

Contrary to the results of standard creep tests, tensile strains under sustained load are relatively limited when the reinforcement is in contact with soil (Bathurst et al., 2005; Carrubba et al., 2000; Tatsuoka, 2008). However, the viscous behavior could still impact the soil-geosynthetic interface under serviceability conditions. Since this issue has not been thoroughly examined in scientific literature nor fully addressed in the design of civil and environmental engineering structures, further detailed research is warranted.

In response to this need, a new large-scale prototype pullout apparatus was developed and built to investigate the time-dependent variations in confined geosynthetic strains under sustained load (Cardile et al., 2021). This essay details the long-term pullout apparatus, presenting preliminary results from tests conducted on geogrids embedded in a compacted granular soil.

2 Experimental study

2.1 Apparatus

The long-term pullout apparatus consists of: a large steel box (625 × 400 × 1700 mm); a pair of metal sleeves 200 mm long; an internal clamp to hold the geosynthetic specimen; a rubber membrane to apply the vertical loads; a reserve tank to compensate for lack of air; a completely mechanical system for the application of the sustained load made up of weights, gear wheels and pulleys; six rotary variable displacement transducers (RVDT) to measure the geosynthetic displacements; and a system for data acquisition.

2.2 Long-term pullout tests

The long-term pullout tests are currently in progress on two twin apparatuses under controlled conditions of temperature and humidity, applying a vertical effective stress of 50 kPa. Two identical specimens of geosynthetic have been chosen (i.e., HDPE uniaxial extruded geogrid) and embedded within a sand with gravel classified as SW according to USCS (ASTM D2487, 2017). The soil was compacted until reaching the 95% of the maximum dry unit weight obtained by Standard Proctor compaction tests (UNI EN ISO 13286-2, 2010). Sustained pullout loads have been set to 50% and 70% of the peak pullout resistance obtained by a pullout test performed according to ASTM D6706–01 (2013) at a constant rate of displacement (CRD) of 1 mm per minute, under the same vertical effective stress.

3 Long-term behavior of the geosynthetic

Displacements recorded at various points along the geogrid have been utilized to compute the confined tensile strains, σ_{conf}, over time. These strains have been compared to those from tensile creep tests performed in-air at the same loading level, showing that they are lower. Furthermore, the confined strains exhibit a reduced gradient due to the mobilization of pullout interaction mechanisms along the geogrid. Should this trend continue, the time to reach potential creep rupture under pullout conditions would be significantly extended compared to the time observed in conventional creep tests. This finding implies that the creep reduction, which is used to decrease the tensile strength of geosynthetics in current design practice (ISO/TR 20432, 2007), may be overly conservative.

4 Long-term behavior of the interface

The design of geosynthetic-reinforced soil walls and slopes typically utilizes Limit Equilibrium methods (LEM), which require the determination of the apparent coefficient of friction between soil and the geosynthetic ($\sigma_{s/GSY}$). Considering the impact of creep phenomena on the deformation of geosynthetics over time, it is essential to examine if the apparent coefficient of friction should be reduced to account for these factors. To explore this matter, isochronous curves on a $\mu_{s/GSY}$–σ_{conf} plane have been built, where σ_{conf} represents the strains calculated along the geogrid section nearest to the clamp. Two different $\mu_{s/GSY}$ values have been computed for the two different levels of sustained load tested experimentally; for each load level, the σ_{conf} strains mobilized at specific times have been also calculated. The resulting isochronous trend has been derived from the curve fitting of the $\mu_{s/GSY}$–σ_{conf} pairs, demonstrating that reinforcement strains in the anchorage zone continually increase. It is important to verify if their final value achieved at the end of the design working life is compatible with the structure serviceability.

5 Design procedure

When design methods based on the ultimate limit state are employed, the design parameter $\mu_{s/GSY}$ could be selected using the $\mu_{s/GSY}$–σ_{conf} isochronous curves to also address the serviceability limit state. A design procedure has been defined (Fig. 1) and it involves entering an isochronous $\mu_{s/GSY}$–σ_{conf} graph with a horizontal segment representing the allowable strain for a given structure. When this segment intersects both the curve for strain at the end of the design life and at the end of construction, the corresponding $\mu^{LTC}{}_{s/GSY}$ value (long-term creep apparent coefficient of friction) can be read in the vertical axis.

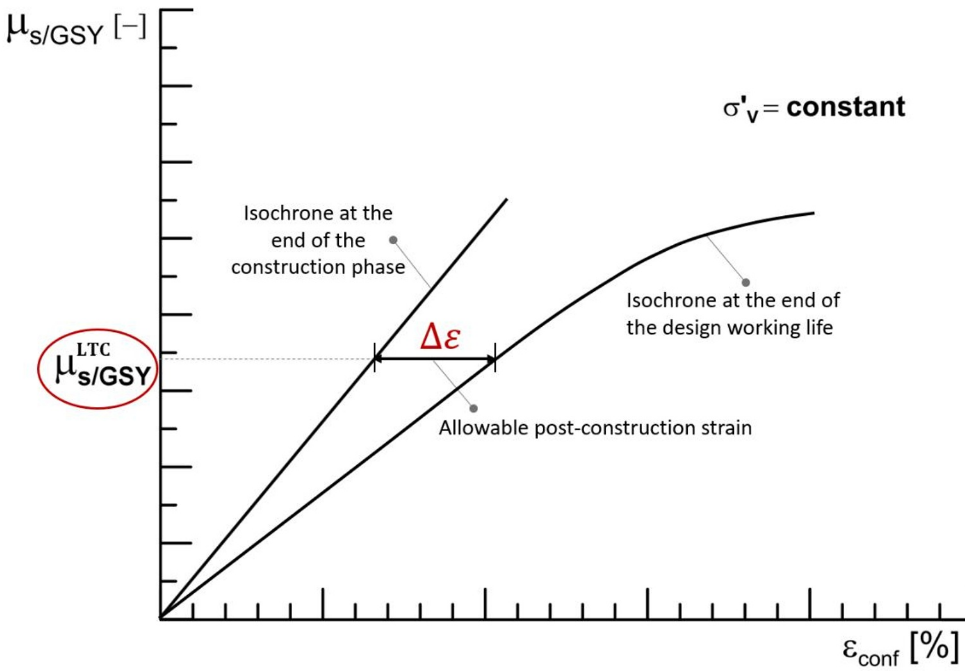

Figure 1: Long-term apparent coefficient of friction assessed at a prescribed limiting value of post-construction strain in reinforcement by using isochronous curves (modified from Cardile et al., 2021).

6 Conclusions

This essay presents a novel large-scale prototype apparatus designed to analyze the long-term pullout behavior of a soil-geogrid interface under a sustained tensile load:

- Preliminary results indicate that the strains accumulating in the confined reinforcement are lower than those observed in standard tensile creep tests, suggesting that the creep reduction factor may be overly conservative.
- Isochronous curves have been constructed to correlate the apparent coefficient of friction mobilized at the interface with the geosynthetic confined strains under a sustained load. These curves indicate that

the current selection of interface parameters may result in tensile strains incompatible with the structure serviceability.

- A procedure has been proposed to ensure that limit equilibrium analysis, typically focused on the ultimate limit state, also accounts for aspects related to the serviceability limit state.

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