Analysis of physical PET strap reinforcement pullout tests data

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Abstract. The present work compiles results from pullout tests campaigns carried out in recent years. Tests are focused on polyester (PET) strap reinforcement of varied grades (or ultimate tensile strengths and, consequently, stiffness) subjected to different confining pressures and installation conditions. Reinforcements have homogeneous HDPE sheaths with continuous surfaces. Assessments of possible post-pullout damage and the consequences of said deterioration are explored. General conclusions regarding design and construction practices are commented.

1 Introduction

Design of reinforced soil structures typically considers working stress conditions (i.e., far from failure conditions), where, even for extensible geosynthetic reinforcements, maximum strains are not expected to surpass a 1% threshold (Miyata et al. 2018). The use of strap reinforcements (and other geosynthetic materials) requires a proper characterization of the interface shear behaviour between the embedded load-bearing elements and surrounding soil. Pullout tests are particularly useful to quantify interface shear response, including strength and stiffness parameters required for an optimized reinforcement design while ensuring safety conditions. The present study details several pullout tests carried to evaluate the performance of polyester (PET) strap reinforcement, with a special emphasis on the effect of different installation conditions observed in the field.

2 Test procedure

Test were carried out in a rigid steel box, measuring 1250 mm in length, 500 mm in width, and 750 mm in height. Dimensions were selected in accordance to ASTM D6706-01 (2021). Figure 1 shows the laboratory equipment, including installed instrumentation. Past pullout test campaign for polymeric and steel reinforcements carried out by the authors, including soil characteristics, in-depth equipment and procedure description, and numerical simulations of results can be found in Damians et al. (2024).

The present work is focused on the qualitative rather than quantitative assessment of installation methods for polymeric straps. For this, three types of tests were carried out. First,

 https://doi.org/10.1051/e3sconf/202566201004

standard pullout tests with a reinforcement length of 900 mm (see Figure 2a) were undergone.

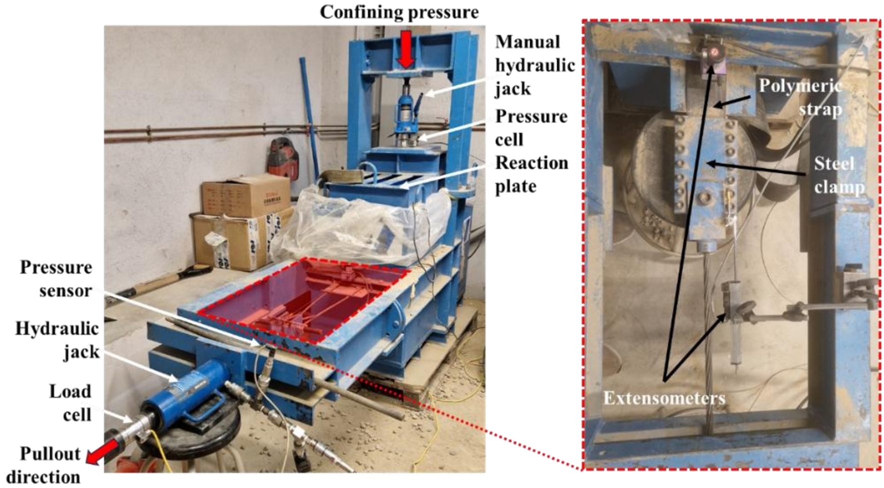
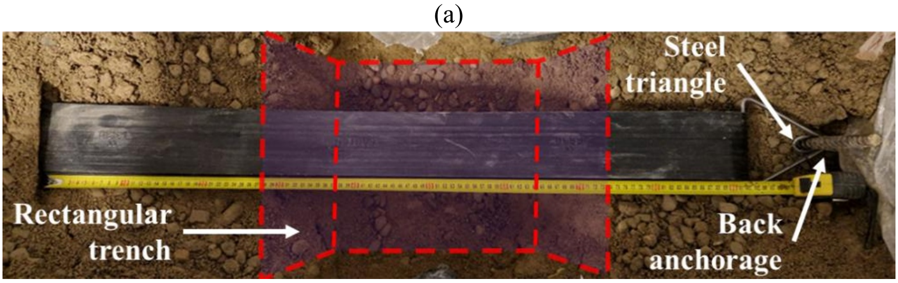


Figure 1: Pullout test equipment located in the geotechnical laboratory of the DECA in UPC.

(a)



(b)

Figure 2. Polyester strap configuration (Grade 30) for (a) standard tests with variable embedded length (900 mm in the figure) and (b) modified test with a back anchorage system and rectangular trench to simulate real installation conditions.

Second and third, using a tail-end anchorage system, pullout tests were carried out with and without a rectangular trench in the middle of the reinforcement length (see Figure 2b), respectively. The back anchorage system is composed of a 400-mm-long steel rod tied to a 100-mm-high bent steel triangle. The purpose of both elements is to simulate common installation practices used to remove wrinkles and slightly pre-tension the reinforcement straps. The trench section consists of an almost-vertical, 200-mm-deep, 400-mm-long trench covering the whole width of the pullout box, resulting in an effective reinforcement length of 500 mm. As soil was placed a-top the reinforcement, only the sections outside the trench where properly compacted (i.e., the area outside the red section in Figure 2b). For all conditions, vertical loads were applied to simulated depths of 0.3-m, 3-m, and 7-m. Test were carried out using 90-mm-wide, 3-mm-thick PET strap reinforcements with an HDPE sheath with an ultimate tensile strength of 34.4 kN/strap at 11.2% strain.

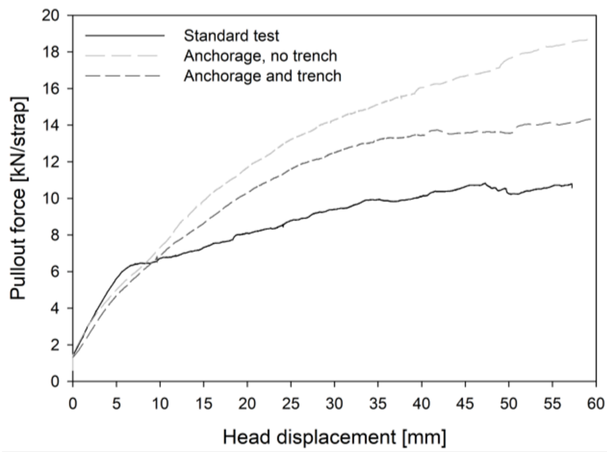


Figure 3. Pullout force results at z = 7 m for a smooth-surface, grade 30 PET strap reinforcement considering standard and modified test conditions (see Figure 2).

A scenario in which the reinforcement was directly put inside the trench (i.e., without the back-end anchorage) was not tested as it was not considered a representative representation of in-field installation practices.

3 Test results

Figure 3 shows pullout load (in kN/strap) and head displacement (in mm) for a simulated depth of 7 m. Results include three different tests (i.e., using a conventional setup, with a back-end anchorage, and a back-end anchorage including a trench under the middle of the reinforcement). Obtained results show that the presence of a trench increases pullout capacity. Likewise, the presence of the tail-end anchorage provides further pullout capacity. Results at 3-m and 7-m of depth showed that the presence of a trench is detrimental to the pullout capacity when compared to the anchorage strap, contrary to the 0.3-m of depth results. Results show a matching initial trajectory, up to approximately 8 mm of displacement, between the three scenarios. Likewise, both test with tail-end anchorage (with and without a trench), share a common trajectory up to 12 mm of displacement, approximately. These displacement values match to the initiation of tail-end displacements for each case. The use of an anchorage results in increased stiffness at the tail-end of the reinforcement, meaning that
relative displacements occurred at a higher pullout load, nevertheless, the development of the pullout load will first depend on the soil-reinforcement interaction and reinforcement stiffness. It must be noted that, after each test, the steel triangle used to fix the polymeric strap with the anchorage rod presented severe deformations.

For the standard and anchorage-only (i.e., no trench) tests, specimens presented slight (barely visible) sheath damage. For tests with a trench and tail-end anchorage, strap reinforcements suffered noticeable damage to the protective sheaths, mainly located at 300 mm from the pullout box metal sleeve, which matches the beginning of the excavated trench. Sheath damage consist of ruptures (no larger than 30-mm in length) and small indentations. Observed damage appears to be limited to the protective sheath, meaning that the load-resisting polyester fibres remain exposed but (possibly) unharmed, even after over 50-mm of head displacement. In theory, under service conditions, the stresses at the end of the reinforcement are near to, if not, null, meaning that the damage caused by the existence of a trench under the strap near the tail-end should only be a concern for extreme situations (e.g., high seismic demand). Be it that the case, the lack of visible damage to the polyester fibres indicate that short-term structural instabilities should not be of concern. On the other hand, the exposure of PET fibres could represent an opportunity for long time deterioration. Moisture can easily reach fibres, leading to concerning chemical damage, depending on pH, for example. Likewise, further relative movement between the soil and reinforcement could results in further damage to the fibres.

4 Conclusions

- Pullout test using PET strap reinforcements were carried out simulating 0.3-m, 3-m, and 7-m of depth with different boundary conditions. Test included loose and tail-end anchoraged straps as well as a partial-length trench beneath the reinforcement.
- The use of an anchorage, with and without a trench, results in increased pullout capacity. For the fixed tail-end cases, at 0.3 m of depth, pullout capacity is increased with the excavated trench, while decreasing at 3-m and 7-m of depth.
- After pullout failure, straps were carefully exhumed and inspected. Every test yielded slight damages to the HDPE sheath. Scenarios with a rectangular trench presented the most severe damage, particularly within the beginning of the excavated area.
- Sheath damage after pullout failure could lead to a progressive long-term degradation of the reinforcement which should be explored.

Acknowledgements

The authors wish to thank A. Kim from GECO Industrial (Korea, Rep.) for providing polymeric strap samples. The authors wish to acknowledge the support of the Department of Civil and Environmental Engineering (DECA) of the Universitat Politècnica de Catalunya·BarcelonaTech (UPC) and the International Centre for Numerical Methods in Engineering (CIMNE) and the funding received from the Spanish Ministry of Economy and Competitiveness through the “Severo Ochoa Programme for Centres of Excellence in R&D” (CEX2018-000797-S-20-4).

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