Louisiana Transportation Research Center

Technical Summary Report 380

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Evaluation of Interaction Properties of Geosynthetics in Cohesive Soils: Lab and Field Pull Out Tests

Introduction

The increasing use of geosynthetics to reinforce walls and slopes has raised the need to evaluate the reinforcement interaction parameters (i.e. pullout resistance and shear stress-strain characteristics) in a wide range of soil types, including cohesive soils and low-quality backfills. In determining the geosynthetics' interaction parameters in such soils, many factors can influence the measured properties. These factors are related to the testing equipment and associated boundary effects, soil properties and compaction procedures, geosynthetic type and geometry, and confining pressure.

The soil-geosynthetic reinforcement interaction mechanism is complex and raises difficulties in interpreting the pullout test results. The confined stress-strain of the geosynthetic during pullout is significantly affected by its geometry, length, extensibility, and the amount of soil confinement. Pullout resistance of geotextile reinforcement is provided mainly by friction resistance along the soil-geotextile interface. On the other hand, the pullout resistance of a geogrid is due mainly to soil frictional resistance and passive bearing resistance against its transverse members. Furthermore, non-uniform shear stress-strain distribution is developed along the geosynthetic specimen during pullout due to the coupled effect of its elongation and interface shear. Various theoretical and empirical procedures have been developed in order to model the soil-geosynthetics interface mechanism during pullout. These models vary in their assumptions with respect to the constitutive material properties, the load transfer mechanism at the interface, and the shape of the load-strain curve during pullout.

In order to evaluate the behavior of reinforced soil walls constructed with low-quality backfill, the Louisiana Transportation Research Center (LTRC) has constructed a reinforced test wall with silty-clay soil backfill.

Objectives

The objective of this research was to evaluate the pullout performance of geogrids and geotextiles in silty-clay soils. The results were correlated for various types of geogrid and geotextile reinforcements. This report presents an evaluation of the pullout resistance parameters for this type of soil.

Research Approach

Field pullout tests were performed on geogrid and geotextile specimens placed between the main reinforcement layers in one section of the test wall. The geogrids used in the testing program included: Tensar UX750, UX1500, UX1700, and Stratagrid 500. The geotextiles tested were Synthetic Industries woven Geotex 4x4, Geotex 6x6, and Evergreen nonwoven TG700. These materials included weak and strong reinforcement types and covered a wide stiffness modulus range.

Principal Investigator:
Khalid Farrag, Ph.D., P.E., LTRC
Mark Morvant, P.E., LTRC

LTRC Contact: Mark Morvant, P.E.
Phone (225) 767-9124

Louisiana Transportation Research Center

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4101 Gourrier Avenue
Baton Rouge, LA 70808-4443
www.ltrc.lsu.edu

Laboratory tests were performed on the geosynthetic specimens in the same type of silty-clay soil used in the test wall and at comparable confining pressures. The hydraulic testing equipment used in the laboratory tests was also used in the field tests in order to provide the same control and pullout rates. In both tests, the soil was compacted to 95 percent of its standard proctor density at optimum moisture content. Various length specimens from 3 ft. to 5 ft. were tested in the field while the laboratory tests were performed only on 3-ft. long specimens.

The analysis of test results included a comparison of laboratory and field tests. The analysis focused on an evaluation of the pullout design factors (Ci, F*) and whether these factors complied with FHWA design procedures.

Conclusions

This report presents the results of laboratory and field pullout tests on various types of geogrids and geotextiles. Field and lab pullout tests compared well for flexible geogrids and geotextiles (Tensar UX-750, Stratagrid-500, and Geotex-4x4). However, pullout results in the field were significantly higher than lab results for rigid geogrids (Tensar UX-1500 and UX-1700). Field test results on the rigid geogrids also showed that the strains at the front elements were higher and the pullout resistance was not fully mobilized along the whole length of the specimens.

Pullout tests were performed a few months after the construction of the wall. The consolidation of the silty-clay soil underneath the wall and soil drying may have resulted in a field density and moisture that differed from the lab values. Because rigid geogrids obtain a high percentage of their pullout resistance from the passive bearing resistance of their thick cross ribs in contrast to thin geogrids, the effect of the changes in soil confinement and density between the lab and field tests are more significant in the rigid geogrids.

Pullout tests in the field showed that longer specimens had higher pullout resistance. However, the effect of specimen length is not as significant as confining pressures. The increase in the pullout load resulting from an increase in the specimen length was also insignificant at the early stages of the tests. This is due to the fact that shear strength progressively develops along the specimen length and the effect of specimen length is only recognized near peak loads.

As the interface shear resistance is not uniform along the geosynthetics, pullout resistance becomes a function of specimen length and extensibility. Pullout coefficients F* and Ci are commonly used in order to account for the uniformity of the shear stress distribution and the scale effect of the specimen, respectively. The direct approach to determining the value of F* coefficient involves direct shear tests with the geosynthetic specimen at the interface. The value of F* can then be used with the results of the pullout test to calculate the coefficient. However, the use of both parameters in the pullout equation does not necessitate their separation. Thus the results of lab and field pullout tests were used to evaluate the combined effect of the parameters on the pullout resistance of the various geosynthetics. The values of the pullout coefficient multiplier (F*) depend on the type of geosynthetic and its geometry, length, and confining pressure. The effect of these parameters was determined from the results of lab and field pullout tests. The coefficients decreased with the increase in confining pressure and specimen length, and they increased with the increase of reinforcement extensibility.

Recommendations

Pullout tests can be used to determine the interface parameters of geogrids and geotextiles in cohesive soils. Laboratory pullout tests should be performed in testing conditions identical to the ones in the field since the results are highly dependent on soil confining pressure, density, moisture content, and geosynthetic types.

The combined multiplier factor (F*, Ci) developed in this study for silty-clay soils should be used to determine the effect of the soil confining pressure, geosynthetic length, and stiffness for the types of geogrids and geotextiles used in the testing program. These coefficients are used in the internal stability analysis of reinforced soil structures according to FHWA design procedures.