Louisiana Transportation Research Center

Technical Summary
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Evaluation of the Effect of Synthetic Fibers and Non-woven Geotextile Reinforcement on the Stability of Heavy Clay Embankments

Introduction

The seasonal variation of soil moisture is a common phenomenon in poorly drained embankment slopes of cohesive soils. An increase in moisture content, usually observed after rainfalls, causes a decrease in soil shear strength and results in a reduction of slope safety. In the past, natural heavy clay was used to construct embankments in Louisiana, which has resulted in stability problems today in some areas of Louisiana. Highway maintenance crews spend many hours combatting this problem annually. The rehabilitation technique currently used by maintenance crews entails reshaping the failed slopes to resemble the original grade with minimal moisture control or compaction effort. Unfortunately, this technique does not solve this problem effectively and these slopes will usually fail again with subsequent rainfalls.

Louisiana Transportation Research Center (LTRC) has conducted this research to evaluate two possible methods for the rehabilitation of embankment slope failures. The first method involves the reinforcement of the cohesive soils with randomly oriented synthetic fibers. Previous studies have shown an improvement of soil shear strength when fibers were mixed with the soil. The second method includes the reinforcement of slope with non-woven fabric. When the non-woven fabric is used, the tension forces mobilized in the geotextile enhance the overall stability of slopes. Therefore, both methods can potentially be used in DOTD's daily maintenance repair activities.

Objectives

The objectives of this study were to evaluate the effects of soil density, moisture content, fiber content, and confining pressure on the shear strength of the clayey-fiber matrix, and of soil moisture content and confining pressure on the interface friction between non-woven fabric and clayey soils; and evaluate the effects of construction procedures and of wet and dry cycles on the performance of fiber-soil matrix and non-woven fabric-reinforced embankment slopes.

Scope

This study evaluates two methods for repairing slope surface failures of clayey soil embankments. One method involves reinforcing cohesive soils with randomly oriented synthetic fibers, while the other method incorporates non-woven fabric. The performance of soils reinforced using these two methods were studied both in the laboratory and in the field.

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Research Approach

Soils tested in the laboratory study were obtained from failed slopes. The general physical properties of these soils (e.g. Atterberg limits, particle size distribution, optimum moisture content, and maximum dry density) were determined in accordance with respective ASTM specifications. Large direct-shear testing was used to determine the shear strength of compacted clayey soils with and without goesynthetic reinforcement. The effects of other potentially important factors on the mechanical behaviors of reinforced soils, such as moisture content, confining pressure, and fiber content, were also investigated. Subsequently, the optimum conditions for the development of shear strength of reinforced soils were determined.

The long-term performance of two reinforcement methods was evaluated by constructing and monitoring field test slopes. Five test slopes reinforced with randomly oriented fibers and two test slopes reinforced with non-woven fabrics were constructed at various locations along LA 15. Two vertical inclinometers were installed at each testing slope to monitor the deformation. One was placed at the top of the slope near the highway's shoulders and the other was placed at the midpoint of the slopes. These were used to determine horizontal deformations at these depths of the slopes and, thus, to estimate the locations of possible slip failure surfaces.

Conclusions

Laboratory results showed that the increase in moisture content in clayey soil has a detrimental effect on its shear strength and that fiber-reinforced clayey soils can increase shear strength up to 50%. Field investigation showed that slope surface failures occur when the surface water trapped in fissures and cracks soaks the adjacent soils. Tests of the long-term stability of fiber-reinforced slopes were not conclusive since no appreciable difference was observed in the inclinometer deformations among the soil control sections and fiber-reinforced sections. No significant long-term movement was observed in the fabric-reinforced sections although there was a higher initial vertical inclinometer reading.

The results from this study indicate that using the non-woven fabric to repair failed embankment slopes is a good option to prevent repetitive slope surface failures. When the non-woven fabric is used, it not only generates the tension forces to enhance the overall stability of slopes, but also prevents the development of pore water pressure trapped in clayey soils by providing horizontal drainage through the fabric. It also has the advantage of a relatively low material cost of about $0.50 - $0.75 per square yard.

Recommendations

There is no complicated design procedure to follow when repairing man-made embankments of conventional 3:1 or flatter slopes constructed of high PI soils. Twelve to fifteen-inch vertical spacing can be used with the fabric reinforcement. The slope's back cut will control the width and length of the fabric. The repair process consists of excavating the soil along the failed slope to a depth below the failure plane. The back slope should be benched approximately 3 to 5 feet on an effective slope to insure the stability of embankments under roadways during construction. Wet embankment soils should be spread and allowed to dry before being placed in lifts of 12 inches. Each lift should be placed on a gradient to allow gravity flow of moisture through the fabric to the slope surface. Soils should be compacted to about 95% of maximum dry density, as close to the optimum moisture content as possible. The fabric is placed on the top of each lift in one continuous sheet and is extended about 4 inches outside the slope facing. This method is recommended to maintenance engineers for repair of failed embankment slopes consisting of high PI soils.