TEXAS STATE UNIVERSITY SAN MARCOS
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PROJECT SUMMARY

Texas Department of Transportation

0-6792: Synthesis on Geosynthetic Reinforced Steep Slopes

Background

Geosynthetic reinforced steep slopes (GRSSs) are a form of mechanically stabilized earth that incorporates polymeric reinforcing elements for the construction of sloped structures with inclinations less than 70°. Geosynthetics provide a means to improve tensile resistance and stability in steep slope applications while also accommodating budgetary restrictions and alleviating space constraints. In addition to repairing failed slopes, geosynthetics have also been introduced for the construction of new embankments, for the widening of existing embankments, and as an alternative to retaining walls. The Texas Department of Transportation (TxDOT) currently has limited use of geosynthetics for steep slope reinforcement, and to sufficiently employ this construction technique, knowledge of soil conditions, slope geometry, design criteria, construction sequence, and performance is required. Therefore, a synthesis study on GRSSs was conducted to enhance the present understanding of this technology.

What the Researchers Did

A comprehensive review of literature was performed by the research team to investigate GRSS design and construction methods that exist both nationally and internationally. All factors identified in the literature were analyzed for their potential to improve or replace those currently in use. The review further examined the impact and significance of GRSSs in order to more effectively achieve technical objectives and identify prospective benefits of the project. Transportation agencies, educational institutions, consulting engineers, manufacturers, material suppliers, and construction contractors were identified that have experience with geosynthetics and mechanically stabilized earth structures. Researchers then developed and conducted a survey using a questionnaire based on the project objectives. After receiving approval from TxDOT, the survey was uploaded to an online survey site. The online survey allowed the respondents to take the survey remotely in their own time frame, and then stored responses internally to be accessed and downloaded by the research team at their convenience. Based on the survey results, researchers identified sources that could provide information to develop case studies where the construction of GRSSs has been recently completed. A case study template was subsequently produced that focused on numerous characteristics of existing slopes, including foundation and embankment soil conditions, geometry of the slope prior to and after construction, design equations and criteria, construction methods, material performance, location, and cost. To obtain supplementary information and professional insight, experts were also identified from the survey and interviewed via telephone.

What They Found

Following the Federal Highway Administration design guidelines is the most advocated approach for designing GRSSs, and the methodology has been verified through extensive experimental evaluation. Safety factors, performance limits, and material properties are used to establish the adequacy of reinforcement, earthwork, and structural foundation design features. Other common design methods have been developed by Jewell, Leshchinsky, and Eurocode. Internal and external stability is considered, including rotational,

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sliding, bearing, and lateral failure. Interactive software is also available for engineers to independently design and analyze projects.

Many site-specific characteristics contribute to the overall cost of GRSSs, including cut-fill requirements, wall/slope size and type, existing soil type, available backfill materials, and facing finish as well as temporary or permanent application. For reinforced slopes, the approximate costs of the principal components are as follows: reinforcement 45–65 percent, backfill 30–45 percent, and face treatment 5–10 percent. When comparing reinforced and unreinforced slopes, a benefit and cost analysis is required to justify whether the cost of the GRSS is justified over the alternative flatter unreinforced slope with its increased right-of-way and material costs. Additionally, GRSSs can provide many benefits over retaining walls, such as cost savings obtained by the elimination of deep foundations, ease of construction, and speed of construction.

In the case studies, constructing GRSS was determined to be the most practical and cost-effective option when compared to alternative mechanically stabilized earth structures. Budget constraints and environmental concerns favored slope solutions that lowered costs and offered greener profiles. Due to the ease of constructability and the economy of reinforced slopes, many owners were able to obtain cost savings up to 50 percent over alternative systems. Typically, minimal distress or deformation to the structures was observed due to extensive monitoring during construction. All failures within the reviewed body of literature were due to improper design in the area of surface and internal water removal or the use of fine-grained silt and clay backfill soils.

What This Means

Findings from this research could yield potential reductions in project costs involving the construction of new permanent embankments and provide cost-effective solutions for the stabilization of recurring slope failures. The research team recommends that TxDOT construct a trial GRSS project using local materials and labor. A comprehensive performance-monitoring program should also be implemented to compare observed behavior to the intended design.

The existing topography, subsurface conditions, and soil properties must be considered when evaluating the site for construction. The investigation should include determining the availability of the required type of reinforced fill and backfill materials. Geogrid or geotextile constructed of polyester, polypropylene, or polyethylene is recommended for soil slope reinforcement. The material should be resistant to heat, ultraviolet light, attack by bacteria and fungi, and all naturally occurring alkaline and acidic soil conditions. Free-draining backfill materials meeting the gradation limits of AASHTO T-27 should be used in the reinforced volume. The reinforced fill should also have a plasticity index less than 20, have a pH level in the range of 5 to 10, and be reasonably free from organic or otherwise deleterious material. Soil density, cohesion, and internal friction angle should be determined and considered in design calculations. Surface water runoff should be collected above the reinforced slope and channeled or piped below the base of the slope. Design of subsurface water drainage features should address flow rate, filtration, placement, and outlet details. If slope facing is required to prevent erosion, the reinforcement at the face should be turned up and returned into the embankment below the next reinforcement layer. Other popular facing elements include a variety of meshes composed of polymers or steel that allow the face to be vegetated after construction. The research team also recommends that TxDOT incorporate the synthesized information into the geotechnical manual and construction specifications for GRSSs. Consideration should be given to design methods, material specifications, and construction guidelines.

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