



Research Development and Technology

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Slope Stabilization with Recycled Plastic Pins

A new technique for stabilizing surficial slides in earth slopes and embankments has been developed for the Missouri Department of Transportation by investigators from the University of Missouri-Columbia. The technique uses reinforcing members, manufactured from recycled plastics and other by-products, to intercept potential shallow sliding surfaces and provide additional resistance to maintain the stability of the slope (Figure 1). The general feasibility of the technique was demonstrated previously at a “proof of concept” site located on Interstate 70 near Emma, Missouri.

Based on the successful implementation at the I70-Emma site, an expanded field testing program was undertaken in 2000 to evaluate the effectiveness of stabilization schemes in varied site conditions and to investigate whether an adequate margin of safety could be maintained using more widely spaced reinforcement schemes. These objectives were addressed by establishing instrumented test sections at five sites and monitoring the performance of each test section since installation.

Field Test Sites

The selected sites were chosen from a pool of over 50 candidate test sites located across the state. The sites include two embankment slopes located on Interstate 435 in southern Kansas City, an excavated slope on U.S. Highway 36 near Stewartville, Missouri, an additional embankment slope at the I70-Emma site (designated Phase II), and an excavated slope on U.S. Highway 54 near Fulton, Missouri. Slope heights at the selected sites range from 15- to 46-ft; slope inclinations vary from 2.2:1 (H:V) to 3.2:1. Subsurface conditions for the different slopes also vary.

Extensive site investigation and laboratory testing programs were performed for each of the selected sites to establish the conditions that are believed to have led to previous failures at the sites. Stability analyses were then performed to evaluate the stability of the respective slopes for different potential stabilization schemes. Results of these analyses were then used to select the stabilization scheme(s) for the respective sites. Variable sta-

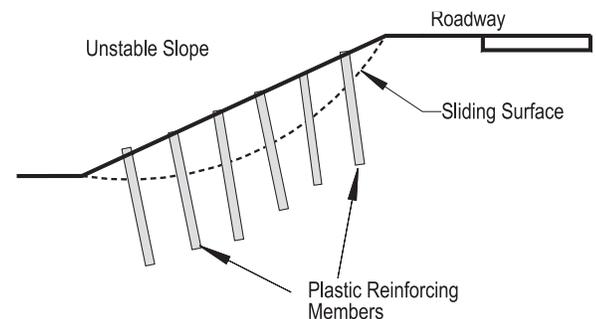


Figure 1. Stabilization of slope using recycled plastic reinforcement.

bilization schemes were used at different sites, and within single sites (Figure 2), so that the technique could be optimized based on the costs and performance of each stabilized section. Stabilization schemes varied from schemes with

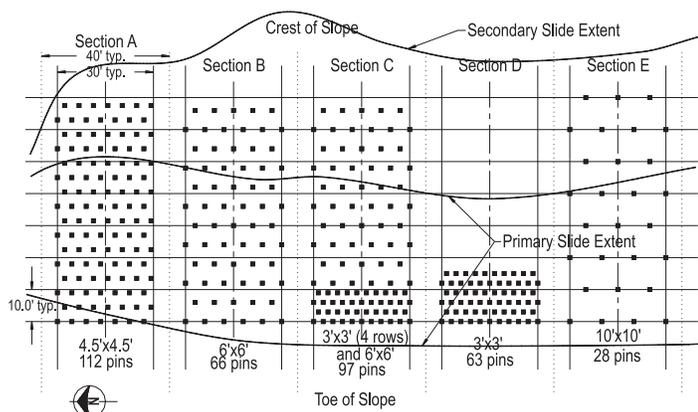


Figure 2. Plan view of US54-Fulton test site showing alternative stabilization schemes utilized at the site

closely spaced members (e.g. 3-ft by 3-ft uniform grid) that are very likely to be effective to schemes with relatively widely spaced members (e.g. 10-ft by 10-ft) that are not likely to provide long-term stabilization.

Field Installation

Reinforcing members were installed using two different types of equipment (Figure 3). The vast majority of members were installed using a crawler-mounted pneumatic rock drill; however, a select number of members were installed using a simple drop-weight hammer mounted on a skid steer loader. Both types of equipment proved to be



Figure 3. Equipment used for installation of recycled plastic reinforcing members.

extremely effective for driving the reinforcing members. Installation rates generally averaged approximately 100 members per day for each type of equipment and peak installation rates exceeded 140 members per day. Installation at the I435-Kansas City sites was completed in December 2001; installation at the US36-Stewartsville site was completed in May 2002 and installations at the I70-Emma (Phase II) and the US54-Fulton sites were completed in January 2003. Following installation, each of the sites was

heavily instrumented with a suite of slope inclinometers, instrumented reinforcing members, standpipe piezometers, and a variety of soil moisture sensors. Instrumentation at each site has been monitored regularly since installation.

Field Performance

To date, no failures have been observed in any of the test sections and all test sections continue to perform well, although test sections at the US36-Stewartsville, I70-Emma (Phase II), and US54-Fulton sites have yet to be subjected to conditions that are believed to have led to prior failure of the slopes. The behavior observed at each site has generally followed a consistent, three stage pattern of behavior (Figure 4). In the first stage, the slopes are observed to experience little movement as a result of favorable precipitation conditions at the site. In Stage 2, additional movement is observed to occur in response to additional precipitation at the site as the resistance in the reinforcing members is mobilized. The slopes are then observed to enter Stage 3, wherein movements in the slopes are observed to cease due to an equilibrium condition being reached as sufficient resistance is mobilized to maintain the stability of the slope. Slopes at the I435-Kansas City sites and the I70-Emma (Phase I) site have exhibited all three of these stages of behavior, while slopes at the remaining sites remain in either Stage 1 or Stage 2. Additional monitoring of these sites is ongoing to establish whether the stabilization schemes established at these sites are sufficient to provide long-term stabilization of the slopes.

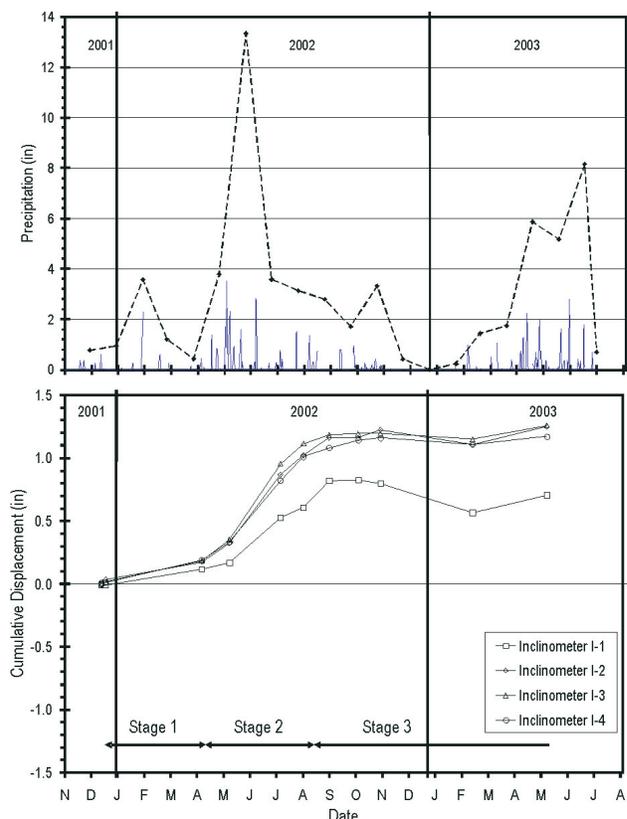


Figure 4. Precipitation and lateral deflections at I435-Wornall Road test site.

Conclusions

- (1) surficial slides can be effectively stabilized using recycled plastic reinforcing members placed in a 3-ft by 3-ft staggered arrangement over the entire slide area;
- (2) long-term stabilization may be possible with more widely spaced arrangements of reinforcing members (with substantial cost savings) but additional monitoring is necessary to more definitively establish minimum required reinforcement patterns;
- (3) the stabilized slopes follow a consistent, three-stage pattern of behavior in response to precipitation experienced at the site and mobilization of resistance in the reinforcement; and
- (4) unit costs for stabilization using recycled plastic reinforcing members vary substantially with the spacing of the reinforcing members (\$4.50/ft² of slope face to less than \$1.00/ft²).

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