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A Combined Semi-Z Anchor and Geotextile System for Soil Reinforcement

by

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Introduction

Applications of the Anchored Earth technique and that of geotextiles for soil reinforcement, have been quite recent. Details of the former, and its first ever field application, have been reported by Jones, *et. al.* (1985), and that of the latter by Broms (1988).

A hybrid of the above mentioned two techniques of soil reinforcement was propoosed by the author (Singh, 1984), particularly for use in embankment situations. The system of reinforcement proposed initially comprised of using mild steel round bar anchors having a specially designed shape at one end, which alternated with a synthetic geogrid over the depth of the reinforced soil structure at a suitable uniform spacing. The U.K. Transport and Road Research Laboratory Z-shaped anchor (Murrey and Irwin, 1981) and Netlon 'SR' geogrid were proposed and expected to be used in the Combined System. In the meantime, a Semi-Z shaped anchor was developed (Singh, Finlay and Sutherland, 1985), followed by the Semi-Z with rounded corner type (Singh and Finlay, 1986; Singh, 1987), as the preferred one, for use in cohesive frictional or non-cohesive frictional fill embankments. The modified Combined System proposed thus stipulated the use of Semi-Z with rounded corner type anchor, which is the subject of an Indian patent filed by the author (Singh, 1990), alternating with a suitable synthetic geotextile rather than the geogrid. Again, instead of a plain geotextile, use was made of a heavy grade polypropylene needle-punched non-woven geotextile, which was bonded on one side on to an open mesh nylon scrim (Singh and Siavoshnia, 1988), and is marketted commercially.

Salient end-results of model studies using a colliery mine waste with particle sizes limited to 20 mm, and a local silty clay, establishing the superiority of the Combined System of soil reinforcement over the fully anchored or fully geotextile-reinforced system is presented in the paper.

Brief details of the first fully anchored Indian prototype, comprising

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of a 2.5 m high vertical-faced approach embankment of a small road bridge constructed in July 1989 at Varanasi are given (Singh, 1989), and a presumptive improved modification incorporating a combined Semi-Z anchor and geotextile system solution is given. The application of the combined system is not only proposed for embankment situations, but also for reinstatement of failed slopes, and a presumptive solution for a slope situation is also given in the paper.

The Experimental Soils

The colliery mine waste (minestone) used in experimentation was the finer than 20 mm fraction of a colliery overburden soil, not subjected to any heat alteration, obtained from the Singrauli coal belt area near Varanasi. The local silty clay was the one obtaining at the site, where the first Indian Anchored Earth prototype was constructed, in the outskirts of Varanasi, in July 1989. Table 1 gives the engineering properties of both the soils.

The Geotextile

An Indian manufactured 100% polypropylene, needle-punched, white, non-woven, heavy grade, geotextile with bonding one side on to an open-mesh white nylon scrim was used in the studies. The addition of the scrim gave the geofabric some added strength, as well as good surface bonding property, for soil reinforcement. The characteristic physical properties of the synthetic geotextile are given in Table 2.

Salient End-Results of Model Studies

The minestone waste with particle sizes limited to 20 mm, and the local silty clay, were used in experimentation, at the moisture contents and dry densities mentioned in Table 1, in a test box having inside dimensions of $735 \times 545 \times 415$ mm, with the front face comprising of five movable interlocking panels of equal widths measuring to an assembled overall dimension of 540 mm width and 340 mm height. The details of the test box, the semi-Z shaped with rounded corner model anchor elements, and the three sets of tests, one each corresponding to the fully anchored, fully geotextile reinforced, and combined anchor and geotextile reinforced system, have been presented by Siavoshnia (1988) and Rai (1989), and reported by Singh and Siavoshnia (1988).

The fully anchored and the fully geotextile reinforced systems had three layers of anchors and three layers of geotextile, respectively installed in the middle of each of the first (I), third (III) and fifth (V) layers of the compacted fill (the five layers of compacted fill correspond with the five movable interlocking facing panels-panel V being the topmost). In the combined system test, the soil sample in the test box was reinforced with

TABDE 1

Engineering properties of the experimental soils

Sl. No.	Engineering Property	Measured value	
		Minestone waste	Silty clay
1.	Natural moisture content	4.5%	8.5%
2.	Specific gravity of solids	2.41	2.65
3.	Particle size distribution (particles coarser than 20 mm were removed from the minestone waste used)		
	finer than 0.002 mm	6.5%	15%
	0.002 mm—0.06 mm	14.5 %	67%
	0.06mm—2.00 mm	73%	18%
	2.00 mm—20.00 mm	6%	0%
4.	Proctor test		
	maximum dry density	1.73 g/cm^3	1.81 g/cm^3
	optimum moisture content	11%	14.8%
5.	Index tests (finer than 0.0063 mm fraction)		
	Liquid limit	19%	31%
	Plastic limit	14%	19%
	Plasticity index	5	12
6.	Classification	CL-ML	CI
7.	Direct shear test at slow rate (0.020 mm/min), to simulate drained condition for sample prepared at the test condition		
	mine stone:		
	dry density of 1.70 g/cm^3, moisture content of 13%	C=0.03 Kg/cm^2 ϕ=28°	
	silty clay:		
	dry density of 1.63 g/cm^3 moisture content of 15%		C=0.05 Kg/Cm^3 ϕ=26°

three layers of anchors (I, III and V panels) and two layers of geotextile in between (II and IV panels).

Geotextile was cut to the dimensions of 635 mm by 540 mm for installation in the test box, and was connected to the respective facing panel by first folding one side of it around a light weight aluminium flat strip, which was then connected by steel screws to the inside face

TABLE 2

Characteristics of the synthetic geotextile

Sl. No.	Physical Property	Measured value
1.	Weight	213 g/m^2
2.	Thickness	2.8 mm
3.	Grab tensile test: Breaking strength	
	(a) Warp way	51 kg force
	(b) weft way	48 kg force
4.	Wing tear test: Tear strength	
	(a) warp way	13.5 kg force
	(b) weft way	11.7 kg force

of the facing panel. A simple nut connection was used for the screwed end of the anchor for connecting to the respective panel. Each layer of anchor comprised of two anchor elements positioned 280 mm apart centrally in the test box.

Load testing of the three systems was done by controlled application of uniformly applied stress increments, through reaction loading, and recording data for movement of panels, and the drop in the top level surface of the compacted fill ('settlement'), till the test reached failure or near failure condition.

Applied vertical stress versus 'settlement', and lateral displacement of panel V versus applied vertical stress curves, for each of the three tests described, and for both the experimental soils, are shown in Figs. 1 and 2, respectively. The curves for the other panels were similar though they showed smaller displacements than for panel V.

Discussion of the Results

Figure 1 shows that the 'settlement' (drop in the top level surface of the compacted fill) shown by the combined system for any given vertical stress applied is much less than that shown by the other two systems. Likewise, Fig. 2 shows that the lateral displacement of panel V exhibited by the combined system for any given vertical stress applied is much less than that exhibited by the other two systems. These observations were equally valid for both the soils tested.

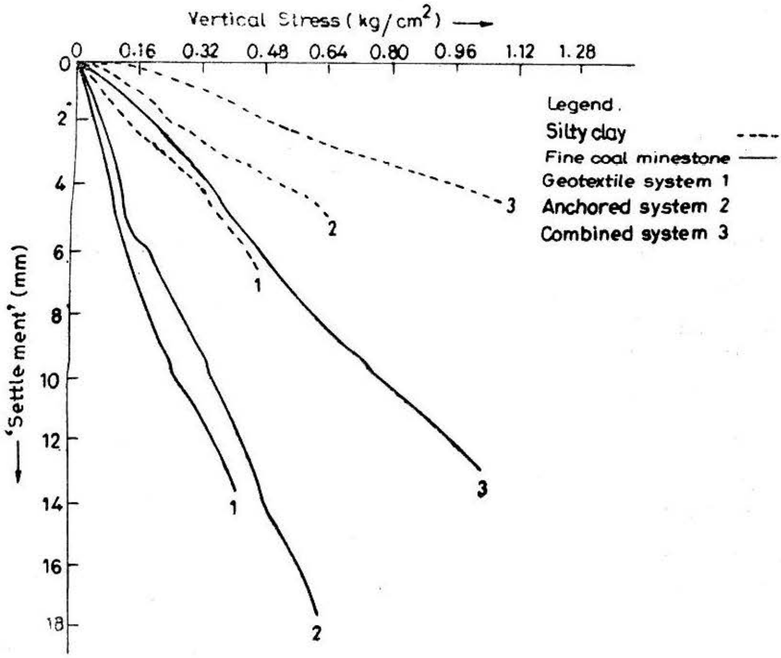

FIGURE 1 Applied vertical stress versus 'settlement' curves

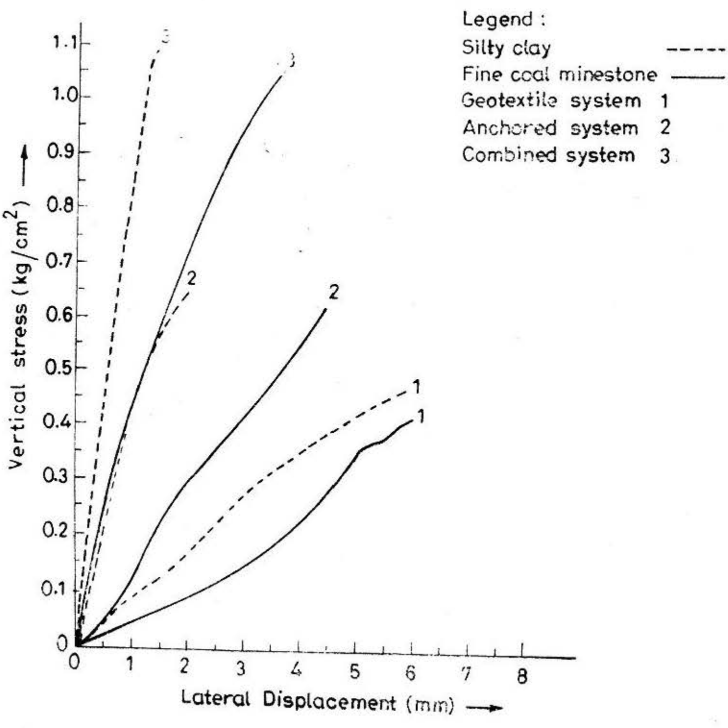

FIGURE 2 Lateral displacement of panel V versus applied vertical stress curves

Thus, the two figures clearly indicate, that in the increasing order of their holding capacities, the three systems could be arranged as a fully geotextile reinforced system, the fully anchor reinforced system and the combined anchor and geotextile reinforced system.

Combined System Modification for the First Indian Anchored Earth Prototype

The first Indian fully anchored structure, constructed in July 1989 at Km. 2 of Bela-Pahadia Road, Varanasi, was a vertical-faced approach embankment for a reinforced cement concrete slab type small bridge (culvert) of 3 m span. Its details of design, construction and performance have already been presented (Singh, 1989; Singh, *et. al.* 1990; Singh and Agrawal, 1991).

Figure 3 shows the cross section of the presumptive Combined System modification for the first Indian Anchored Earth structure mentioned above. The change introduced in the original design pertains to the provision of synthetic permeable geotextile strips cut in square sizes of 3.5 m × 3.5 m, and located centrally between adjacent layers of anchors, as shown in the figure.

It is expected that the modification as suggested above, could result in substantial increases of the holding capacity of the prototype structure.

Combined System Solution for Reinstatement of a failed slope

Figure 4 shows the cross section of the presumptive Combined System solution for the reinstatements of a failed earth slope.

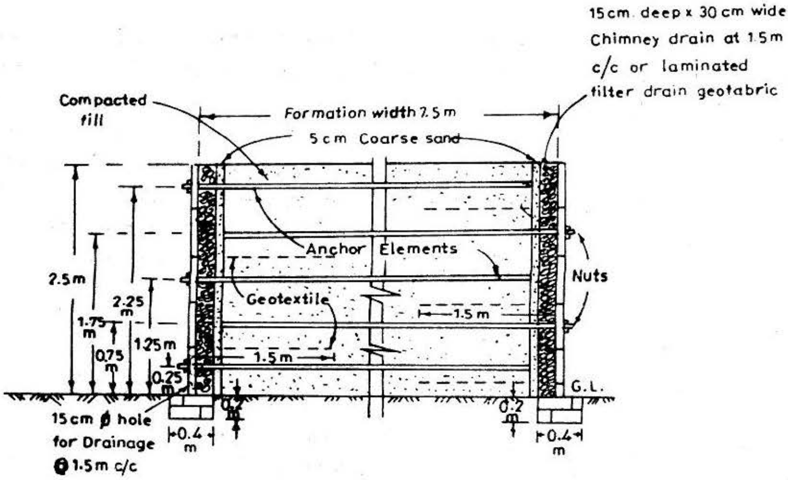

FIGURE 3 Showing cross-secticn of the Combined System modication for the First Indian Anchored Earth prototype

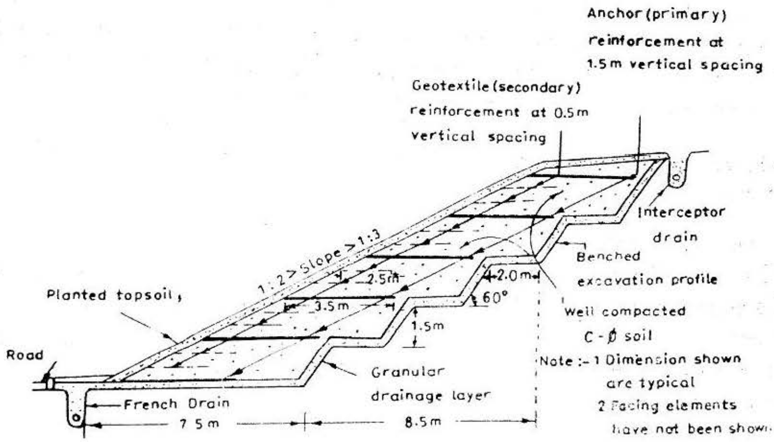

FIGURE 4 **Showing cross-section of a typical failed earth slope reinstatement proposa. using Combined System of soil reinforcement.**

Semi-Z shaped with rounded corner anchors serve as primary reinforcement at a spacing of 1.5 m centre to centre vertical spacing. Synthetic permeable geotextile strips, cut in square sizes of 2.5 m × 2.5 m, and located in pairs, one above the other at a spacing of 0.5 m centre to centre vertical spacing, in between two adjacent primary anchors, constitute the second component (secondary reinforcement) of the Combined System solution. Suitable facing elements would have to be provided to hold the primary and the secondary reinforcements in position, and have not been shown in the figure.

Conclusions and Suggestions

Model experimentation using two different types of soils has clearly demonstrated the superiority of the Combined System of soil reinforcement. It is a hybrid system in which the primary reinforcement is provided by Semi-Z shaped with rounded corner type anchors, and the secondary reinforcement is provided by a heavy grade polypropylene needle-punched non-woven permeable geotextile. It was shown that the combined system is the most efficient, followed in the descending order of effectiveness by the fully anchored system, and the fully geotextile reinforced system.

A presumptive improved modification of the original fully anchored design of the first Indian Anchored Earth structure, which was constructed in July 1989 near Sarnath in Varanasi, based on the combined system, is given. Another presumptive solution for the reinstatement of a failed earth slope based on the combined system is also given to illustrate the versatility of the new system. A combined Semi-Z anchor and permeable synthetic geotextile system is recommended for general adoption for soil reinforcement. Further similar research studies are suggested with different geofabrics and different soil materials in order to evolve rational design criteria for the combined system of soil reinforcement.

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