PERFORMANCE OF GEOSYNTHETICS IN SWELL – SHRINK BEHAVIOR OF EXPANSIVE SOILS

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ABSTRACT

Ground movements associated with swelling and shrinkage characteristics of expansive clays during winter and summer respectively, pose a serious threat to most of the civil engineering structures, especially those of imposing light to medium stresses over the underlying expansive clays. In this paper an attempt is made to control the swell - shrink potential of expansive clays using geosynthetic material viz geogrid, geomembrane, geocomposite and geotextile. Swelling and shrinkage tests were independently conducted on compacted expansive clays with varying number, orientation and end confined geosynthetic materials. From the results, it is observed that the swell potential of clay decreases with increasing of number of layers of geosynthetics and the order of reduction in swelling potential is geomembrane > geogrid > geocomposite > geotextile. End confined geosynthetics controls swelling to 50 – 80% higher than the case of unconfined geosynthetics. Vertically placed geogrid reinforcement controlled the swell better than the one that is horizontally placed. However, no effect on the swelling potential is observed because of vertically placed geotextile or geomembrane. Unlike swelling, horizontally placed geogrid and geocomposite controlled the shrinkage potential for about 50% to 60% higher than the vertically placed one.

Keywords: Swelling, shrinkage, geosynthetics

INTRODUCTION

Environmental conditions of a particular area in which expansive soils are located play an important role in the behaviour of such soils. The frequency of rainfall, rate of evaporation, along with the amount or depth of expansive clay and the activity of clay are the parameters in the eventual heave of expansive soils. The alternate swelling and shrinkage cause differential movement in the structure build over such soils and result in damage to pavements, damage to building, damage to canals and damage to conduits (Gromko 1974).

Ramanatha Ayyar et al. (1989) examined that the soil reinforcements are most effective when they are placed close to the footing. The mechanism of resisting heave in swelling clay does not seem to arise from friction between the clay and the geosynthetics, the possible passive resistances provided by thick meshes seemed to govern the resistance. Dange and Thakarae (1996) reported that the provision of geomembrane on the top surface of expansive soil mass effectively restrains the heave and swell pressure of underlying expansive soil. Sridharan (1999) attempted to study the use of soil reinforcement technique for the control of heave. In all the reinforced cases, steady state (rate of change of settlement zero) was reached without causing failure. The amount of settlement be observed in the reinforced cases was very much less than that of unreinforced expansive soil. The increase in stability is due to additional strength from the frictional interaction between reinforcement and soil. Craig and Rowe (2000) reported that not much difference in swelling behaviour for the GCLs examined at higher stresses but as the stress level decreased, the method of manufacturing appeared to exhibit more control over the swelling behaviour. Stalin and Jeyapriya (2001) had shown that the introduction of geogrid and geotextiles enhanced the rate of swelling but did not control the magnitude of swelling of expansive clays and whereas geomembrane controlled the swelling of expansive clay by 50%.

Srinivasamurthy (1994) evaluated the shrinkage behaviour of fine grained soils in the unsaturated state with different initial conditions by conducting shrinkage limit test on three different samples and found that the initial state (structure) does not really affect shrinkage limit for saturated state. Ambily

(2001) concluded that time-shrinkage curves generally follow a rectangular hyperbola relationship irrespective of the soil type. It was also found that the size of samples has a large influence on the amount of shrinkage, and the magnitude of shrinkage was decreasing with increasing sand content. In this paper, swell – shrink characteristics of expansive clays with single and multiple layers of geogrid (GG), geotextile (GT), geomembrane (GM), and also geocomposite (GC) in vertical and horizontal orientations were carried out.

EXPERIMENTAL PROGRAMME

Materials

The soil used in this study was collected from Anna Nagar, Chennai at a depth of 1.5 m from ground level and classified as high swelling nature based on plasticity characteristics and differential free swell index values. The index properties of the soil are presented in Table 1.

Table 1 Physical Properties of Soil

Description	Values
Liquid limit (%)	70
Plastic limit (%)	27
Shrinkage limit (%)	9.1
Plasticity Index (%)	43
FSI (%)	120
Sand (%)	0
Silt (%)	42
Clay (%)	58
Specific gravity	2.72
γ_{dmax} (kN/m^3)	15.9
OMC (%)	25.5
Swelling Classification	High

METHODOLOGY

Swelling Tests in Model Tank

Swelling test was conducted in a mould of diameter 100 mm and height of 36 mm, the soil sample was statically compacted in layers to a height of 12 mm at 8 % moisture content. The geosynthetic materials were cut into a size equal to the inner diameter of the swelling mould and placed at 1/2 and 2/3 of the sample height respectively for one and two layer of geosynthetics. The samples were then submerged in water with a surcharge pressure of 5 kN/m^2. Dial gauges were fixed and the time-swelling observations were taken until equilibrium values reached. In order to conduct the swelling test with end-confined geosynthetic material (in horizontal direction), the parts of the swelling mould is connected by grooving arrangement. The schematic view of swelling test set up for soil with two layers horizontally placed geosynthetic is shown in Fig. 1.

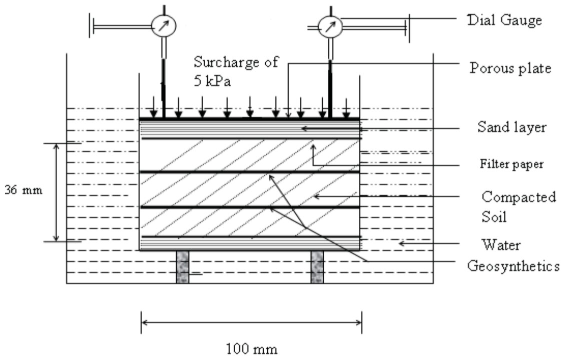

Fig. 1 Swelling test setup for soil + two layer geosynthetics in horizontal orientation

Shrinkage Test on Fabricated Mould

Shrinkage studies of soils were conducted on specially fabricated shrinkage cups without base whose dimensions are 70 mm diameter and 30 mm height (Fig. 2). The shrinkage ring was placed on a perplex sheet with filter paper at the bottom. Then the ring was filled with remoulded soil at liquid limit consistency, with and without geosynthetics, sand, flyash and quarry dust and was allowed to dry at room temperature. The changes in vertical and horizontal shrinkage of the soil samples were measured regularly at time intervals of 0, 2 hr, 4 hr, 8 hr, 11 hr, 24 hr, 48 hr, 72 hours etc., until shrinkage completes.

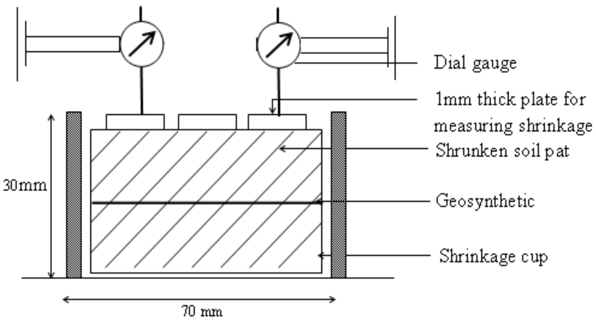

Fig. 2 Experimental setup for shrinkage test with geosynthetics

RESULTS AND DISCUSSIONS

Influence of Type of Geosynthetics on Swelling

Figures 3 and 4 present the time-swelling relationship of soil with one and two layers of geosynthetics placed in horizontal orientation. Up to 1000 minutes, there is an overlapping of time-swelling curve with all the four geosynthetic materials. Beyond, 1000 minutes time interval, swelling was always lower for geomembrane and higher for geotextile where as geocomposite and geogrid lie in between. The reduction in swelling is in the order of geomembrane > geogrid > geocomposite > geotextile. Same is the order in two layers of geosynthetics. Reduction in swelling among the material is the least for soil with geomembrane compared to other geosynthetic materials. It is attributed due to passive resistance mobilized because of swelling of clay below the membrane. During the swelling process, water was allowed to enter the clay system from both top and bottom.

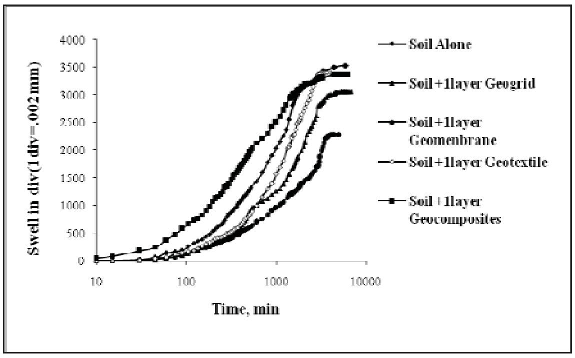

Fig. 3 Effect of geosynthetic material on time-swelling curve for one layer with horizontal orientation

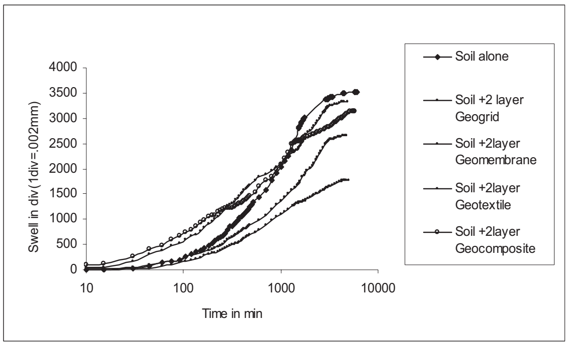

Fig. 4 Effect of geosynthetics material on time-swelling curve for two layers with horizontal orientation

The bottom portion of clay layer upon swelling exerts pressure on the geomembrane. In such a situation, if the geomembrane is treated as a wall and clay layer below geomembrane is taken as backfill, then the passive resistance developed is responsible for overall reduction in swelling of clay. Earlier Ramanathan Ayyar (1989) opined that the reduction in swelling of clay with the use of geosynthetics is due to passive resistance. Even though the magnitude of swelling is less in the case of soil+ geomembrane compared to soil + geotextile, but still rate of swelling is always higher for the case of later. It may be because geotextile is having very good drainage characteristics and because of which water can enter easily and thereby rate of swelling is enhanced. Geocomposite also has shown a similar trend as seen in the time-swelling curve. Dange and Thakarae (1996) reported that performance of geomembrane on the top of surface of expansive clay effectively controlled the swelling of underlying soil.

Influence of Orientation of Geosynthetics on Swelling

Figures 5, 6 and 7 show the time-swelling relationship for soil alone, soil + one layer of geogrid in vertical and horizontal direction, soil + one layer of geotextile in vertical and horizontal direction, soil + one layer of geocomposite in vertical and horizontal direction respectively. It is observed that time-swelling relationship generally follow typical 'S' shape curve. Even though, in the initial portion of swelling, there is not much variation on the effect of orientation in time-swelling, curve for all the three materials namely geogrid, geotextile, geocomposite, however considerable reduction in swelling could be seen on the effect of orientation of geosynthetics at higher time interval. In general, vertical orientation reduces the swelling considerably higher than horizontal orientation for geogrid, geotextile and geocomposite. Upon swelling, by allowing water from both top and bottom, the soil above the geosynthetic material can freely swell and if at all the swelling of bottom clay layer alone is controlled by horizontal orientation of geosynthetics. But on the other side as the soil is swelling, because of the fullest mobilization of friction between the geosynthetics and surrounding clay along the vertical direction for the entire height of the sample, the swelling could be effectively controlled unlike the case of horizontal orientation. Sridharan et al. (1987) reported that the swelling of expansive clays are controlled in the direction of swelling. However, the swelling is controlled, in the present case, much effectively in vertical direction rather than in horizontal direction.

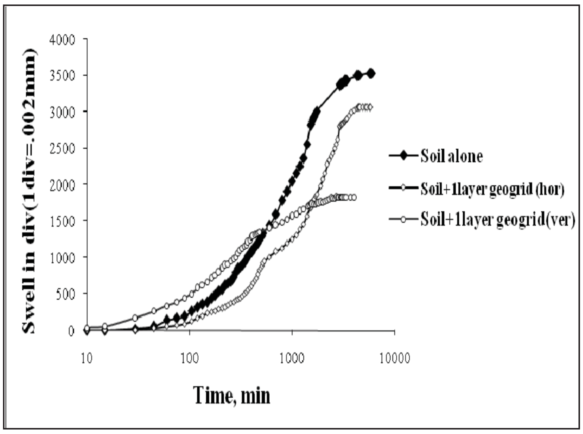

Fig. 5 Time-swelling curve for vertical and horizontal orientation of geogrid

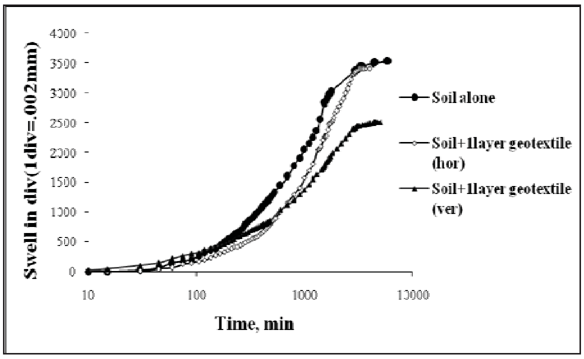

Fig. 6 Time-swelling curve for vertical and horizontal orientation of geotextile

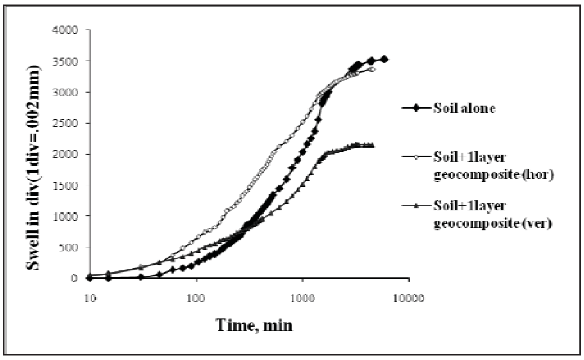

Fig. 7 Time-swelling curve for vertical and horizontal orientation of geocomposite

Influence of Number of Layers of Geosynthetics on Swelling

Table 2 presents the effect of number of layers of geogrid, geomembrane, geotextile, and geocomposite on swell control. As the number of layer increases there is considerable reduction in the swelling of each geosynthetic material. In the case of soil + geogrid the reduction is 13.4% for one layer and same is 25% for two layers, for geomembrane the reduction is 36% for one layer, and 50% for two layers (Fig. 8). For geotextile and geocomposite reduction in swell with one and two layers are marginal. It is well known that increasing the number of layers of geogrid will generally result in proportionate increase of bearing capacity and reduction in settlement due to enhanced friction at the interface of soil and geogrid (Jones 1985). Friction that is mobilized between soil and geosynthetic material are responsible for the reduction in swelling magnitude. When number of layers is increasing, the contact point for the development of friction also would be increasing and result of which the swelling is getting reduced. From figure 8, it is clear that either one or two layer of reinforcement, reduction in swell is always higher for two layers geomembrane compared to two layers geogrid, geotextile and geocomposite.

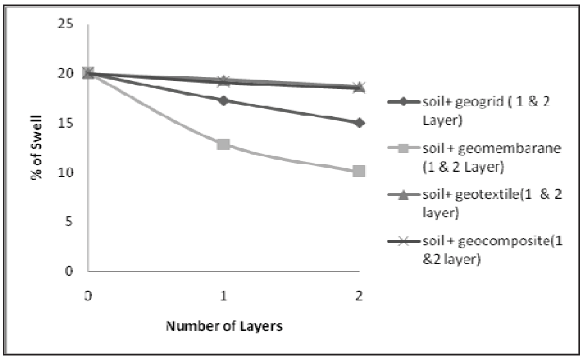

Fig. 8 Effect of number of layer of geosynthetics on % swell

Table 2 Effect of number of layer of horizontally placed geosynthetics on % swell

Description	% Swell	% Reduction in Swell
Natural Soil (2)	20.00	-
Soil+1Layer geogrid	17.30	13.5
Soil+1Layergeomembrane	12.87	35.66
Soil+1Layer geotextile	19.31	3.39
Soil+1Layer geocomposite	19.13	4.36
Soil+2Layer geogrids	15.03	24.84
Soil+2Layer geomembranes	10.04	49.82
Soil+2Layer geotextile	18.72	6.40
Soil +2Layer geocomposite	18.49	7.42

Effect of End Confinement on Swelling

When expansive soil swells, it exerts pressure on the geosynthetic layer above. In such cases, there is every possibility for the geosynthetic layer to deflect upward and thereby there will not be effective control of swelling. In order to arrest the movement of geosynthetic layer at the same time to have effective control of swelling, swelling tests were conducted with end confinement. Figures 9 and 10 show one layer of geogrid and geomembrane for the case of with and without end confinement. The reduction in swell for soil + one layer of geogrid without and with end confinement are respectively 14% and 36%, for geomembrane it is 36% and 85%, and for geocomposite it is 4% and 20% (table 3). In the case of end-confined geotextiles with soil, the swell reduction is 32% and for same material without end confinement gave a reduction of only 3.4%. Among the four geosynthetic materials used soil with one layer of geomembrane with end confinement resulted maximum reduction in swell, which is 49% less than the soil with geomembrane without end confinement (table 3).

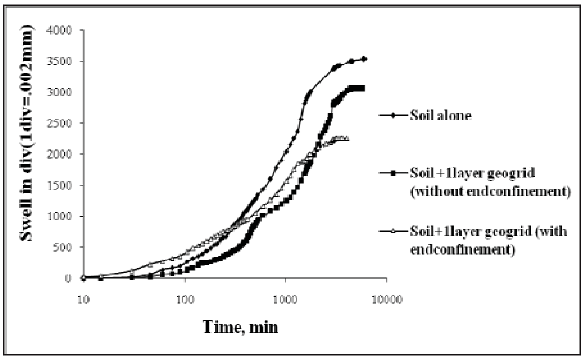

Fig. 9 Time-swelling curve for geogrid with and without end confinement

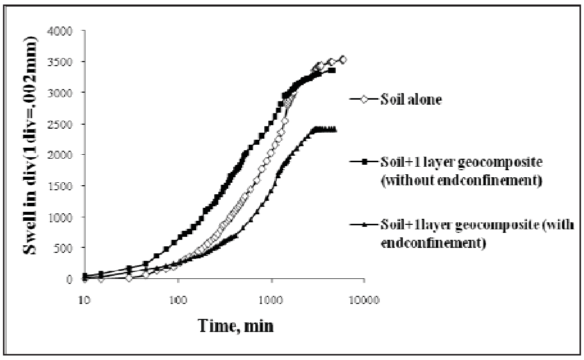

Fig. 10 Time-swelling curve for geocomposite with and without end confinement

Table 3 Effect of end confinement of geosynthetics on % swell

Description	%Swell	
	Without End Confinement	With End Confinement
Soil alone	20	20
Soil+1 Layer geogrid at middle	17.30	12.76
Soil+1 Layer geomembrane at middle	12.87	3.08
Soil+1 Layer geotextile at middle	19.31	13.67
Soil+1 Layer geocomposite at middle	18.49	15.95

Influence of Geosynthetic Material on Vertical Shrinkage

Figures 11 and 12 show the time-vertical shrinkage curve for the case of horizontal orientation of four different geosynthetic materials. At any point of time, soil with geomembrane is giving the lowest shrinkage compared to the other geosynthetic materials, for both one and two layers of the same. The reduction in shrinkage is in the order of geomembrane > geotextile > geocomposite > geogrid. The changes in shrinkage for soil with geosynthetic material can be explained as follow. Shrinkage is the process of evaporation of moisture from the soil system. The truncated shape of the shrunken soil pat is observed when geomembrane is provided in horizontal direction at the mid of the layer of 30 mm, it is because geomembrane did not allow moisture to evaporate and the clay layer below the geomembrane did not shrink at all. As the shrinkage is not uniform in the case of soil + geomembrane within the size of the sample of diameter 70 mm and 30 mm height, shrinkage is found to be always lesser compared to the other geosynthetic materials. On the other side when geogrid and geocomposite are used, lots of cracks were found to be developed during the process of shrinkage is only indicating the non-uniformity of the shrinkage in both horizontal and vertical direction (Fig. 13).

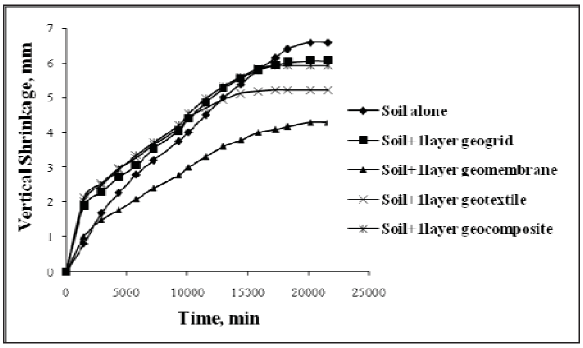

Fig. 11 Effect of geosynthetic materials on time–vertical shrinkage curve for one layer with horizontal orientation

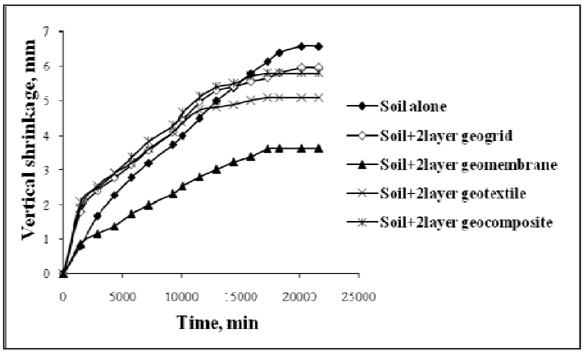

Fig. 12 Effect of geosynthetic material on time–vertical shrinkage curve for two layers with horizontal orientation

If the shrinkage is uniform, there will not be any development of cracks in either horizontal or vertical direction. As provision of geogrid and geocomposite are giving resistance in the direction in which it is provided, there is no homogeneity of the soil mass that shrinks in vertical and horizontal direction. In fact, lot of cracks found to propagate within 3 days after the sample was allowed to shrink, which only confirm the anisotropic shrinkage behaviour.

However, cracks were not found to develop in case of geotextile and geomembrane (Fig. 13). It may be because, the geomembrane is a smooth material and as such the friction at the interface (i.e. soil and the geomembrane) did not develop as it happened with the other materials and possibly because of which even no cracks were found in top portion of soil above the geomembrane or geotextiles whether it is one or two layer cases. For the case of soil + geotextiles, the geotextiles material is found to get compressed during the process of shrinkage and being so no cracks were found either with one or two layers of geotextiles (Fig. 13).

Fig. 13 View of shrunken sample of soil and soil + two layer of geosynthetics in horizontal orientation

Effect of Orientation of Geosynthetics on Vertical Shrinkage

Figures 14 and 15 show the effect of orientation of geocomposite and geotextile on the vertical shrinkage values of soil for different time interval. The shrinkage of clay is always lower for the case of horizontally placed geotextile and geocomposite compared to the vertically placed one. This is possibly because of effective mobilization of friction at the interfaces of soil and geosynthetics upon swelling of soil mass in the horizontal direction.

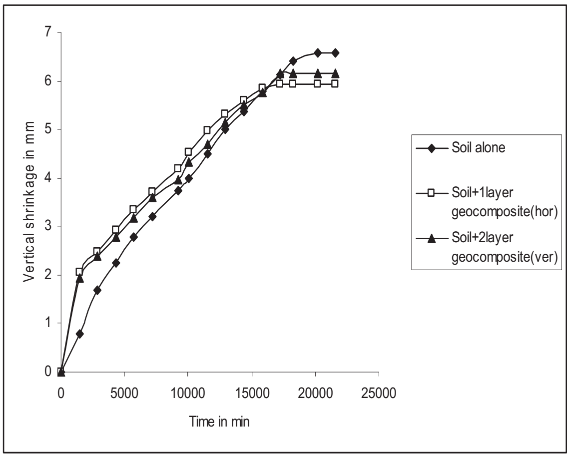

Fig. 14 Time-vertical shrinkage curve for vertical and horizontal orientation of geocomposite

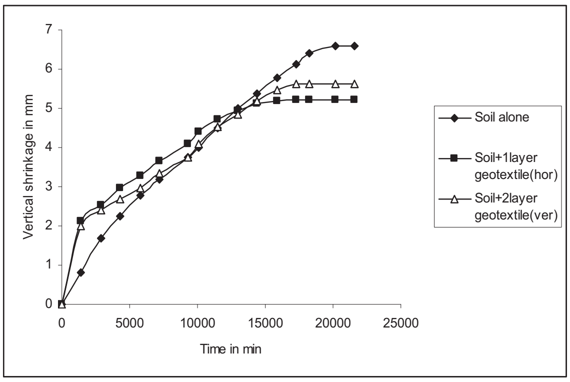

Fig. 15 Time-vertical shrinkage curve for vertical and horizontal orientation of geotextile

Influence of Number of Layers of Geosynthetics on Vertical Shrinkage

Figures 16 and 17 show time-vertical shrinkage curve for one and two layers of different geosynthetic material. The shrinkage of soil with two layers of geosynthetic material always yields shrinkage value lower than one layer. Soil alone has shrunken 6.58 mm and corresponding percentage shrinkage is 22%, whereas soil with one layer of geogrid, geomembrane, geotextile and geocomposite are 6 mm, 4 mm, 5.2 mm and 5.9 mm respectively. For the case soil with two layer geosynthetics the vertical shrinkage are 5.9 mm, 3.6 mm, 5 mm and 5.8 mm respectively. Thus it is clear that two layers of geosynthetic material reduce the shrinkage better than one layer. This may be due to friction mobilized at the interfaces of soil and geosynthetic material, upon volume reduction. From Fig. 18, it is clear that the reduction in vertical shrinkage is significant with number of layers of geosynthetics compared to horizontal shrinkage. For any number of layers of geosynthetics the shrinkage is the least for geomembrane and high for geogrid.

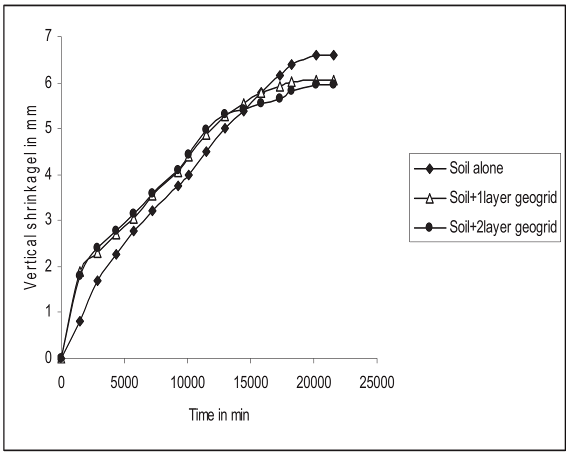

Fig. 16 Time –vertical shrinkage curve for one and two layer geogrid

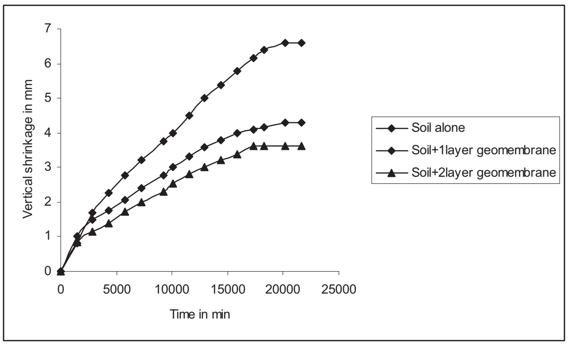

Fig. 17 Time –vertical shrinkage curve for one and two layer geomembrane

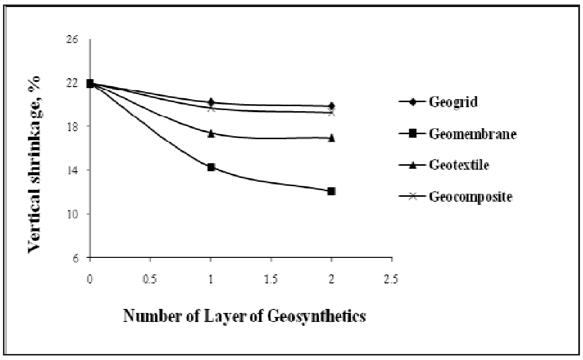

Fig. 18 Effect of number of layer of geosynthetics on vertical shrinkage

CONCLUSIONS

From the swell - shrink tests conducted on expansive clay with varying number and orientation of geogrid, geomembrane, geotextile and geocomposites, the following conclusions may be drawn

1. Among different geosynthetic materials used, introduction of geomembrane into the clay system is found to control the swelling of expansive clay significantly compared to other materials. The reduction in % swell is as high as 50% for the case of one layer of geomembrane in clay sample without end confinement. The reduction of % swell is in the order of geomembrane >geogrid > geotextile > geocomposite.
2. For any geosynthetic material, the one which is confined at the edges, is found to control the swelling 30 to 40 % higher than the same material without confinement. In the case of soil + two layers of geomembrane with end confinement, the swell reduction is 85 % .The swell reduction is attributed to the passive resistance mobilised on the geomembrane.
3. Geosynthetic material placed vertically gave the higher swell reduction compared to the same material placed in horizontal direction, especially this is true for the case of geogrid and geocomposite. This may be due to the development of friction between the soil and geogrid for the entire sample height unlike the case of soil with horizontally placed geogrid, where soil below the geogrid gives raise to friction and wereas soil above is allowed to freely swell. On the contrary, horizontally placed geosynthetics controls shrinkage much higher than the vertically placed one.

LIMITATIONS

Swelling of clay can be controlled if expansive clay is to be used as an embankment material above ground level. But it is practically cumbersome to control the swell potential of expansive clay using geosynthetics below ground level and also deeper depth owing to the difficulties over the placement of geosynthetics.

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