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Geosynthetics : An Overview

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ABSTRACT

Soil stabilization is one of the most popular techniques used for improvement of poor subgrade soils like black cotton soil and silty soil. Black cotton soil has high shrinkage and swelling behaviour with variation in moisture content, due to which failure of pavement occur. In silty soil slaking and dispersion occurs leading to formation of voids as proper bonding between individual particles are lacking. To overcome these problems it is necessary to improve the properties of soil by reinforcement or by replacing the soil itself. Replacing the existing soil might not be an economically viable option. The reinforcement materials used are in the form of fibers which are randomly oriented or in the form of sheets which are placed in layers in soil. Geosynthetics are man-made materials formed from synthetic fibers like polypropylene, polyethylene, polyester or natural fibers like coir, jute and ramie. More recently the use of geosynthetics in particular geotextile made of synthetic fiber in machine direction and natural fiber in cross machine direction (hybrid) are coming up. This paper describes the available knowledge on the use of geosynthetics in soil reinforcement applications particularly in the field of soil subgrade stabilization. The different categories of geosynthetics and their functions were also discussed.
Keywords: Geotextile, Subgrade, Strength, Pavement

I. INTRODUCTION

Geosynthetics are used to strengthen, elevate and make possible cost effective geotechnical, environmental and transportation engineering construction projects. This improved performance of pavement due to geosynthetics reinforcement has been attributed to three main mechanisms i.e. lateral restraint, increased bearing capacity and tensioned membrane effect. They have a bright future because of their multifunctional characteristics i.e. separation, filtration, reinforcement, drainage, moisture barrier, protection and surface erosion control. With the inclusion of geosynthetics as reinforcement at the optimum position of subgrade, leads to considerable reduction in crust thickness of pavement and rut depth with the increase in CBR value of soil. The reduction in crust thickness saves the costly sub-base and base aggregates which were not either easily available or beneficial in terms of cost and in a developing country like India cost plays a very important role. The need for frequent maintenance and resurfacing is eliminated. So geosynthetics provide a good alternative in improving the load carrying capacity of soils.

The present study focuses on the types of geosynthetics, their functions and reviews the work of various researchers on stabilization of poor subgrade soil.

II. TYPES OF GEOSYNTHETICS

Broadly there are eight categories of geosynthetics: (1) Geotextiles, (2) Geogrids, (3) Geomembranes, (4) Geosynthetic clay liners, (5) Geofoam, (6) Geocells, (7) Geocomposites, and (8) Geonets.

Geotextiles - According to ASTM D4439, the geotextiles are defined as “A permeable geosynthetic comprised solely of textiles”. Geotextiles are further classified in to three categories namely woven, non-woven and knitted. Figure 1, Figure 2 and Figure 3 represents various types of geotextiles.

Figure 1. Woven Geotextile

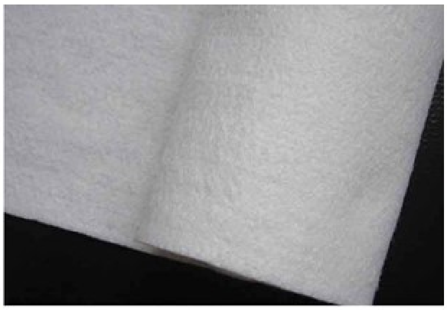

Figure 2. Non-Woven Geotextile

Figure 3. Knitted Geotextile

Geogrids – Geogrids have open grid like structure to allow interlocking with soil, rock or any nearby material. They can be either uniaxial, biaxial or triaxial depending on number of directions it is being stretched for improving its physical properties. Figure 4 shows the biaxial geogrid.

Geomembranes – Geomembranes are impervious thin sheets of polymeric materials used primarily for linings of canal, landfill, radioactive or hazardous waste liquid and it controls expansive soil from swelling thus reducing pressure on superstructure. Figure 5 shows the polymeric geomembrane.

Geosynthetic Clay Liners – Geosynthetic clay liner (GCL) is a thin layer of clay (generally Bentonite) which is placed in between two layers of geotextile and bonded by either needle punching, adhesive or stitch bonding. GCL may also be formed by bonding Bentonite to a geomembrane with an adhesive. Figure 6 represents the geosynthetic clay liner.

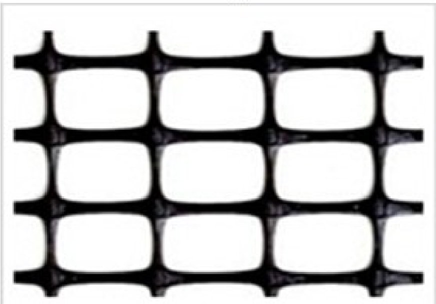

Figure 4. Geogrids

Figure 5. Geomembranes

Figure 6. Geosynthetic Clay Liner

Geofoam – Geofoam is expanded polystyrene (EPS) manufactured into large lightweight blocks. EPS Geofoam is used as lightweight fills for construction on soft soil, stadium and theatre seating, noise and vibration damping, slope stabilization, rail embankment, culverts, pipelines & buried structures, retaining and buried wall backfill. Fig. 7 shows the EPS Geofoam.

Geocells - Geocells manufactured from high density polyethylene are three-dimensional, honeycomb like structures used for containment of soil, gravel and other materials. Geocells are also known as Cellular Confinement. They provide cohesion to cohesionless soils. Their application area includes steep slopes, shorelines, oil and gas roads, sand roads for military vehicles. Fig. 8 represents the polymeric geocell.

Geocomposites – Geocomposites are formed by combination of geotextiles and geogrids or geotextiles and geomembranes or geotextile, geogrid and geomembrane or any other combination such that specific requirements are fulfilled. Each individual unit are bonded or stitched together and they work in unison. Geocomposite formed by combination of geotextile and geogrid are presented in Figure 9.

Geonets - Geonets also called geospacers. They are formed by a continuous extrusion of parallel sets of polymeric ribs at acute angles to one another. When the ribs are opened, relatively large apertures are formed into a netlike configuration. Their design function is completely within the drainage area where they are used to convey liquids of all types. Figure 10 shows the geospacers formed by polymeric materials.

Figure7. Geofoam

Figure 8. Geocells

Figure 9. Geocomposites

Figure 10. Geonets

III. FUNCTIONS OF GEOSYNTHETICS

Geosynthetics mainly perform following five functions namely reinforcement, separation, filtration, drainage and containment. Table 1 shows functions performed by various geosynthetics.

Table 1. Function Of Various Geosynthetics

Types of Geosynthetics	Separation	Filtration	Drainage	Reinforcement	Containment
Geotextiles	✔	✔	✔	✔	x
Geomembrane	x	x	x	x	✔
Geocomposites	✔	✔	✔	✔	✔
Geogrids	x	x	x	✔	x
Geosynthetic Clay liners	x	x	x	x	✔
Geocells	x	x	✔	✔	x
Geofoam	✔	x	x	x	x
Geonets	x	x	✔	x	x

IV. REVIEW OF LITERATURE

The review is mainly concerned with use of geosynthetics for stabilization of poor subgrade soils in terms of improvement of various engineering properties since improved properties leads to saving of natural aggregate materials, reduces settlement, increase service life of pavement and maintenance costs were considerably reduced.

(Elshakankery et al., 2013) studied the benefit of using nonwoven polyester geotextiles as reinforcement of three different Egyptian soils. Five different geotextiles of weight 250GSM, 300GSM, 400GSM, 500GSM and 600GSM were tested. The soils are classified as hard, medium and soft. It was found that improvement in soil properties depends upon soil type with soft soil showing maximum increase in reinforcement ratio value which is 1.07 for 250GSM and it increases to 33.38 for 600GSM geotextile.

(Sivapragasam et al., 2010) studied the effect of using nonwoven polypropylene geotextile on the California bearing ratio (CBR) and unconfined compressive strength (UCS) of clayey soil. Geotextiles were placed in single layer at 3cm, 6cm, and 9cm and in double layer at 3cm & 6cm, 3cm & 9cm, 6cm & 9cm respectively from top of mold. The CBR and UCS value of virgin soil were 1.37% and 0.285N/mm^2 which increases to 2.42% and 0.484N/mm^2 for geotextile placed at 6cm from the top in single layer. The thickness requirement of pavement reduces from 74.22cm for virgin soil to 54.91cm with geotextile.

(Noorzad et al., 2010) studied the effect of geotextile reinforcement on the unconfined compressive strength (UCS) and shear strength parameters of soils. Two soil samples classified as CL and CH (type I and type II) as per USC system and two nonwoven geotextile of 180GSM and 260GSM were used. The geotextile were placed in layers ranging from 1 to 3 at equal spacing. It was found that as the number of reinforcing layer increases there was increase in peak strength value for both type of soil. In case of soil I, increase of cohesion with not much change in internal friction angle and for type II soil, increase in internal friction angle with no considerable change in the cohesion value caused improvement.

(Nair et al., 2009) studied the effect of using polypropylene woven geotextile and biaxial geogrid as reinforcement of poor subgrade soil. The laboratory California bearing ratio (CBR) test were conducted for soil alone, soil-aggregate, soil-aggregate-geotextile and soil-aggregate-geogrid-geotextile system at different water content of 13% (OMC), 14.5%, 16% and 17.5%. The maximum improvement in CBR value was seen in soil-aggregate-geogrid-geotextile system for all water contents.

(**Zornberg et al., 2009)** studied the effect of geogrid reinforcement in mitigation of longitudinal cracks induced in pavements constructed over clayey soil subgrades. Three field evaluations were done on pavements constructed in the Forth Worth-Dallas area, Texas. It has been concluded that geogrid reinforcement minimizes the development of longitudinal cracks, it effectively relocate possible longitudinal cracks beyond the reinforced zone. It has also been found that geosynthetic reinforced portion also show cracks because of failure of geogrid junction due to lower junction efficiency.

(Chore et al., 2011) studied the behaviour of sand - fly ash - polypropylene fiber mixture for road construction. Four different combinations of sand and fly ash were considered in the proportions of 25% - 75%, 50% - 50%, 65% - 35% and 75% - 25% respectively. For each of these combinations the percentage contents of the randomly distributed polypropylene fibers considered were 0, 0.5, 1.0 and 1.5% with two different lengths of 6 mm and 20 mm. California bearing ratio (CBR) and box shear tests were conducted and it was found that maximum increase in CBR and angle of internal friction occurs with fiber content of 1% and fiber length of 6 mm.

The sand gave maximum performance when sand-fly ash was used in 50% - 50% proportion.

(Tang et al., 2007) studied the effect of fiber inclusion on the strength and mechanical behaviour of uncemented and cement treated (5%, 8%) clayey soil. The 12mm long polypropylene fibers in three different percentage i.e. 0.05, 0.15, 0.25% by weight of soil were added. Unconfined compressive strength (UCS) and direct shear test were carried out after 7, 14 and 28 days curing period. The test results indicate that the inclusion of fiber causes an increase in the cohesion, angle of internal friction, UCS and axial strain at failure, behaviour of cement stabilized soil changes from brittle to ductile which is indicated by decrease in post-peak strength loss.

(Basu et al., 2009) studied the effect of jute - high density polyethylene (hybrid) woven geotextile on the CBR value and rut depth of unpaved rural road. It was found that use of hybrid geotextile showed a smooth surface without any significant marks of rutting or subsidence even after 18 months and for portion of road without geotextile 5-35mm deep ruts were visible clearly. The field CBR test conducted after a period of 11 months and 18 months also showed a remarkable improvement, with strength gain of 67% and 73% respectively with use of hybrid geotextile.

(Tuna et al., 2012) studied the effect of mold size and number of reinforcing layers on shear strength parameters of sand by conducting direct shear test. Five types of geotextiles were used in which three were nonwoven and two were woven. Two sand samples namely SW (well graded sand) and SP (poorly graded sand) were used. It was found that in reinforced soils, the loss in shear strength after peak strength was considerably reduced. The cohesion and friction angle increases as the size of mold decreases and number of geotextile layer increases.

(Ingle et al., 2013) studied and presented brief information on geosynthetics product and their standards. The study concluded that the impact of geosynthetic materials (in terms of reduction in the base course thickness) was upto 40% as compared to unreinforced section. Also the design methodologies proposed by various researchers showed the benefit of geosynthetics materials in terms of extension of service life or reduction in the base course thickness. In addition to the savings of costly base and sub-base aggregates there is also considerable reduction in environmental hazardous caused by reduction in transportation through trucks, hence reduction in air pollution due to decrease in diesel demand and less green house gas (GHG) emissions.

(Rawal et al., 2011) studied the various properties of nonwoven hybrid geotextiles of 200GSM and 400GSM which were produced by blending polyester/viscose and polypropylene/viscose fibres in different weight proportions (0%, 20%, 40%, 60%, 80% and 100%). Tensile strength and puncture resistance test were conducted and it was found that the strength and puncture resistance values of hybrid geotextile are not much less than synthetic one and in some combinations it is even more than the synthetic geotextile. Thus it can be concluded that cellulosic fiber like viscose can be successfully used with synthetic fibers for soil stabilization purpose.

(Bera et al., 2011) studied the effect of storing jute geotextile in saturated soil on its strength properties. Six varieties of woven jute geotextiles designated as JG1, JG2, JG3, JG4, JG5 and JG6 having mass per unit area of 670, 560, 235, 800,750 and 500GSM respectively are taken. To know the degradation properties of jute geotextiles, sheets are cut in suitable test sizes and buried into the saturated soil in different layers for a period of 7, 14, 21, 28, 45 days. The wide width tensile strength shows only 10% decrease for (JG6) jute geotextile in cross-machine direction after 45 days of its storage.

(Choudhary et al., 2011) studied the effect of using woven jute geotextile and polypropylene geogrid on the swelling and strength behaviour of expansive soil.

The reinforcement was placed in layers in soil specimen which varies from 1 to 4 and the embedment ratio for the successive layers was kept as 0.25, 0.5, 1 and 1.5 respectively. It was found that in reinforced soil swelling decreases and the amount depends upon number of reinforcing layer and type of reinforcement. The strength improvement in terms of California bearing ratio index (CBRI) value is upto 158% for geogrid and 100% for jute geotextile for 4 layers over unreinforced specimen. Thus geogrid is found to be more effective than jute geotextile.

(Naeini et al., 2009) studied the effect of plasticity index and effect of reinforcement of soft clay on CBR values. Three soil samples of different plasticity index (PI) were obtained by adding bentonite and it was found that as the PI value increases the California bearing ratio decreases and hence the strength in case of unreinforced soil. For reinforcement, geogrid GS-50 made of low density polyethylene fibers having a weight of 300GSM was used. In unsoaked condition inclusion of one layer of geogrid (at top of layer 3) for all soil samples with different PI values causes 40% increase in CBR. However in soaked condition the CBR values increased by about 35% for two layer geogrid inclusion (at top of layer 2 and 4) as compared to unreinforced one.

V. CONCLUSION

Geosynthetics play a very important role in various geotechnical and transportation engineering problems like subgrade stabilization, erosion control, railway works, and containment of liquid and solid wastes. They are invariably cost competitive against soils or other construction materials. Their carbon footprint is very much lower than traditional solutions. Their use in pavement subgrade leads to considerable saving of costly aggregate materials, it helps in rapid construction since can be installed at a greater rate. The improvement caused by them in soil properties is much more in comparison to other conventional materials. Now a day's use of hybrid geotextiles made of natural and synthetic fibers are coming up which overcome the shortcoming of both natural and synthetic geotextiles. To better understand working mechanism of geosynthetics more research is required in this area. Hence it's time to support geosynthetics in sake of better development of our society.

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