Comparative Study of Strength Characteristics of Subgrade Soil Reinforced with Galvanized Steel Mesh and Synthetic Rubber

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Abstract— **The study of reinforced soil as an equivalent homogenous material has been undertaken by many research workers as an attempt to understand its behaviour and to determine its strength characteristics. Reinforced soil is suitable for construction of geotechnical structures because it improves the tensile and shear strength of soil. Various materials like prestressed concrete panels, geotextiles, geogrids, plastics, glass reinforced plastics and timber may be used for this purpose. The incorporation of reinforcement in the earth mass by the use of galvanized steel mesh imparts high tensile stiffness in the direction in which it is stretched. Synthetic rubber is another material used for reinforcing the soil. It is economic and imparts strength when embedded in soil. This research work comprises the comparative study of strength characteristics of subgrade soil reinforced with galvanized steel mesh and synthetic rubber. The strength characteristics of the soil reinforced with galvanized steel mesh and synthetic rubber are found out by conducting laboratory tests such as sieve analysis, water content determination test, specific gravity test, Modified Proctor compaction test, Atterberg limits determination test and CBR test. Analysis of soil reinforced with galvanized steel mesh and synthetic rubber is done and the results are compared to suggest a suitable material.**

Keywords*— *California Bearing Ratio test, galvanized steel mesh, reinforcement, synthetic rubber.

INTRODUCTION

Soil reinforcement has been in vogue in crude form since ancient times. This technique has aroused so much interest and awareness amongst engineers in recent times. It employs prefabricated elements (precast skin units or panels and reinforcing strips, sheet or nets) which can be easily handled, stored and assembled. The flexible nature of reinforced earth mass enables it to withstand large differential settlement without distress. Reinforced earth thus permits construction of geological structures over poor and difficult subsoil conditions. Reinforced earth walls are consequently economical when height of structure is large, or ground conditions are unfavourable and suitable backfill materials are locally available. The reinforced soil is a good technique and an economical alternative to stabilization of natural or artificial slopes. The artificial slopes can be cut off or fill.

There are three basic components of any reinforced soil structure. They are:

i. Soil or fill matrix

ii. Reinforcement

iii. A facing if necessary

In a reinforced soil structure, soil constitutes most of the bulk. A variety of materials including steel, aluminium, rubber, concrete, glass, fibre, wood and thermoplastics may take the form of strips, grids, sheets, ropes, etc. For vertical structures a facing is required to retain the soil between the layers of reinforcements in the immediate vicinity of the facing and to provide a suitable architectural treatment to the structure.

Various materials like galvanized steel, stainless steel, aluminium, bricks, precast concrete slabs, prestressed concrete panels, geotextiles, geogrids, plastics, glass reinforced plastics and timber may be used for this purpose. Strength and load bearing capacity of soil is enhanced considerably when the soil is stabilized mechanically with synthetic rubber. In this research, the strength characteristics of soil reinforced with galvanized steel mesh and synthetic rubber are studied experimentally and the results are compared to suggest a suitable material.

Mustafa Ahmed Kamel et al (2004) has conducted a study on behaviour of subgrade soil reinforced with geogrid and investigated the optimum position of a single layer of geogrid within subgrade soil sample for maximum improvement in strength parameters. M N Asha et al(2010) conducted a study on modified CBR tests on geosynthetic reinforced soil-aggregate systems and found that: i)reinforced soil-aggregate systems performed better when compared to that of unreinforced ones, ii)the effect of boundary is very high in California Bearing Ratio tests and iii) anchorage of reinforcement does not provide any extra benefit to the reinforced soil-aggregate systems. Stephen Archer et al. (2010) studied the performance of a mechanically stabilized layer (MSL) reinforced with geogrids. Shivanand Mali, et.al (2014) reviewed the strength behaviour of cohesive soils reinforced with coir fibers, polypropylene fibers and scrap tire rubber fibers as reported from experimental investigation, that includes triaxial, direct shear and unconfined compression tests.. Huabei Liu (2015) conducted a study on reinforcement load and compression of reinforced soil mass under surcharge loading. An analytical method was introduced to unify the analyses of reinforcement load and compression of a reinforced soil mass under surcharge loading. Pardeep Singh et al. (2012) researched on CBR Improvement of clayey soil with geogrid reinforcement and found that there is considerable improvement in CBR value of subgrade soil due to geogrid reinforcement.

The present study was carried out to find the optimum position of the reinforcements used in a layer of subgrade soil. The reinforcements were placed at different positions and effectiveness of reinforcement layer was investigated through laboratory test such as CBR test.

I. TESTING PROGRAM AND MATERIALS

A. *Material Selection*

The required sample of soil was collected from the site of Chinnakkada Overbridge in Kollam. Three spots in the site were selected for sample collection. Two types of reinforcements were used to reinforce the soil. The various properties of the soil collected are shown in Table 1. The properties of reinforcements are shown in Table 2 and Table 3.

Fig.1 Galvanized steel mesh

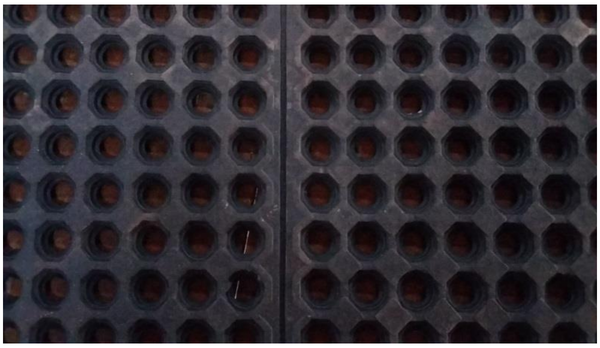

Fig.2 Synthetic rubber

B. *Specific gravity test*

The test procedure was carried out according to IS : 2720 (Part 4) – 1985 – Method of test for soil (Part 4-Grain size analysis). The test was conducted on three samples. The average of the three values was considered.

C. *Grain size analysis*

The percentage of various sizes of particles in the given soil sample was found by particle size analysis. The particle size distribution is obtained by conducting sieve analysis and hydrometer analysis. The tests were conducted as per IS: 2720 (Part 4) – 1985.

D. *Modified Proctor Compaction test*

In this test, the soil is compacted in the Standard Proctor mould (945 ml), in five layers, each layer being given 25 blows of a rammer. IS: 2720 (Part 7) – 1980/87 recommends the use of a 4.9 kg rammer with a drop of 450 mm for heavy compaction. The optimum water content corresponding to the maximum dry density was determined.

E. *Direct shear test*

The specimen in the shear box was filled at maximum dry density. It was then sheared under a normal load. The shear force at failure corresponding to the normal load was measured. A number of identical specimens were tested under increasing normal loads and the required maximum shear force was recorded. A failure envelope is plotted as a function of the shear stress τ and the normal stress σ. The scales of both τ and σ are kept equal so that the angle of shearing resistance can be measured directly from the plot.

F. *California Bearing Ratio test*

CBR tests were conducted on the soil sample unreinforced and reinforced with a single layer of the reinforcements. Every reinforcement was placed in a single layer at different positions namely 20%, 40%, 60% and 80% of the specimen height from the top surface. It was cut in the form of a circular disc of diameter slightly less than that of the specimen to avoid separation in the specimen by the reinforcing layer. The dry weight required to fill the mould was calculated based upon MDD and the volume of the mould. The water corresponding to OMC was added and mixed thoroughly. The samples were tested after soaking in water for 4 days.

TABLE 1. PROPERTIES OF SOIL SAMPLE

Type of soil	Well graded sand
Specific gravity	2.68
Maximum dry density	1.98g/cc
Optimum moisture content	11.9%
Cohesion	0 kPa
Angle of internal friction	35^0
CBR value(unreinforced soil)	5.8%
Liquid limit	Cannot be obtained

TABLE 2. PROPERTIES OF GALVANIZED STEEL MESH

Property	
Form	Sheet
Mesh aperture size	18x18 mm
EA value	$3.5x10^6$ kN/m^2

TABLE 3. PROPERTIES OF SYNTHETIC RUBBER

Property	
Form	Circular mesh
Mesh aperture size	18x18 mm
Thickness	10mm
Weight	1.37g/cm^2
EA value	1766 kN/m^2

TABLE 4. RESULTS OF CBR TESTS FOR DIFFERENT POSITIONS OF REINFORCEMENTS

Type of reinforcement	Position from top (%) of height	Soaked CBR percent
No reinforcement	-	5.80
Synthetic rubber	20(2.5cm)	15.87
	40(5.0cm)	24.31
	60(7.5cm)	29.27
	80(10cm)	27.78
Galvanized steel mesh	20(2.5cm)	30.41
	40(5.0cm)	47.44
	60(7.5cm)	52.78
	80(10cm)	39.68

II. TEST RESULTS AND DISCUSSIONS

Table 4 shows results of the CBR tests of soil reinforced with two types of reinforcements. It is observed that there is a considerable amount of improvement in the CBR value in the reinforced condition. The amount of increase depends upon the type of soil and type of reinforcement used. In the case of synthetic rubber, the CBR value increases from 5.80% for unreinforced soil to 29.27% when it was placed at 75mm from the top and to 52.78% when galvanized steel mesh was placed at similar level. The percent increase in CBR value is more with galvanized steel mesh rather than synthetic rubber indicating that the stiffness of the galvanized steel mesh has considerable effect on the bearing capacity of the reinforced soil.

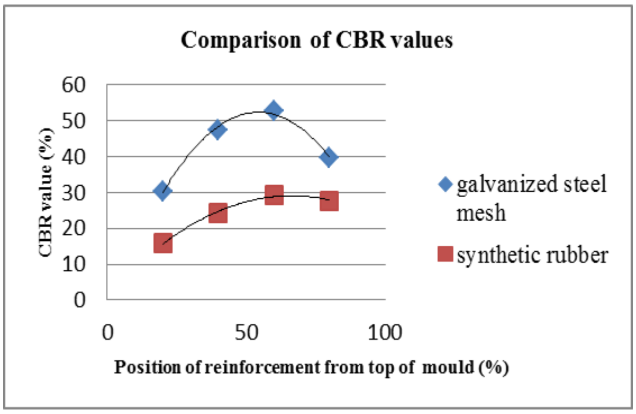

Fig. 3.Optimum position of reinforcement based on CBR values of reinforced soil

A. Optimum position of the reinforcement

The results of CBR tests indicate that for maximum benefit, the reinforcement should be placed in the lower half of the specimen height. The tests were conducted at four different positions of the reinforcement, as shown in Table 4, the maximum value of all strength parameters was observed when the reinforcement was at 60% depth of the specimen height. Placing the reinforcement at 100% depth (below the specimen) is the same as having no reinforcement in the sample. The exact position of the reinforcement was obtained by plotting the increase in the CBR value of the soil with depth of the reinforcement. All these results indicate that the maximum CBR value of the soil is obtained when the reinforcement is placed at about 60% depth of the specimen height.

III. CONCLUSIONS

The study conducted in this paper is to find the optimum position of a single layer of reinforcement within subgrade soil sample for maximum improvement in strength parameters. The results indicate that the maximum effect of reinforcement is obtained when it is placed at about 60% of the specimen height from the top surface. The results also show that the maximum CBR value of 52.78% is obtained when soil is reinforced with galvanized steel mesh which indicates that it is superior to synthetic rubber as soil reinforcement. The sample height in laboratory tests is taken to be equal to the original thickness of compacted subgrade in the field. At this position of the soil, CBR value increases depending upon the type of soil and reinforcement.

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