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An Experimental Study on CBR of Expansive Soil Subgrades using Geotextiles

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Abstract: **The behaviour of the road surface depends upon the strength of the fill material and subgrade below it. Road construction on soft subgrade soil is a major issue affecting cost and scheduling of highway road projects. The strength of subgrade is most often expressed in terms of California Bearing Ratio (CBR) which is the ratio of test load to standard load at specified penetration by a standard plunger. In India the design of flexible pavement is primarily on basis of subgrade CBR (IRC 37-2001).Many techniques have been evolved to strengthen the highway soil subgrade. Among them stabilization techniques are most common. In the Present study stabilisation of soft subgrade soil is achieved by using geotextiles. The objective of this study is to find out an increase in strength mobilization in terms of CBR values, by conducting CBR tests on the subgrade soil when reinforced with geotextiles placed at different positions. Silty expansive clay soil and three varieties of geotextile (HP-370, PEC, and TS-50) are used in the study. CBR tests are conducted with the geotextile placed at different depths from top surface of soil in the CBR mould.**

Keywords: **Geotextiles, CBR, Expansive soils, Subgrade and Woven & Non-woven geotextiles.**

1. INTRODUCTION

For every Civil Engineering construction like buildings, roads, bridges, dams etc, foundation should be very strong. To keep the foundation strong, the construction process on the soil which plays a vital role. If the shear strength of the soil is high then the foundation will be strong. But if the weak soil is encountered in the construction area then it requires strengthening the soil to withstand the loads from super structure along with the self-weight of soil. In general, if the site of construction encounters expansive soils, which are problematic soils always, then there will be a great need for stabilization of the soils. As a general practice, known to everyone, stabilization of such expansive soils is done by the use of admixtures, stabilizers and geosynthetic materials such as geogrids, geotextiles etc. Now-a-days in the construction of roads, the usages of geosynthetic materials are being introduced. A lot of research is ongoing on various types of natural and artificial geosynthetic/geomaterials for introducing at suitable depth of soils with multiple combinations to enhance the strength of the expansive soils.

Synthetic non-woven geotextiles were used by Sivapragasam.C and Vanitha.S. (2010) for road pavements in Virudhunagar district of Tamil Nadu, placed at different depths of soil in single layer and double layers from top of the specimen. According to the study, synthetic non-woven geotextiles were placed at different depth of soil such as 3cm, 6cm, 9cm in single layer from top. Similarly in double layers at 3cm & 6cm, 6cm & 9cm, 3cm & 9cm. The improvement in soil bearing capacity is checked by CBR & UCC test. The results has shown that, single layer of geotextile introduced at center (mid depth) showed better performance than those samples with geotextile at other depths. Naeini, S.A. and Mirzakhanlari, M. (2008) have found that by placing the Non-Woven geotextile sheet (Fibertex F-32) at the middle of the sample height with granular soil has given higher CBR compared to placing the geotextile at top or bottom.

Raut, Aniket. S. et. al., (2016) performed CBR test on the soil sample without geotextile & also by placing Woven geotextile at various depths like 3cm, 6cm, 9cm of the sample height from top. CBR value is more for geotextile placed at 6cm depth (middle) of the sample. Srivastava, Rishi, et.al., (2016) conducted the CBR tests on black cotton soil using woven polyester geotextile by placing at different depths of specimen. Best CBR value observed at 0.4H depth from the top of the specimen.

Bitumen coated Jute fibre has increased the CBR value of the subgrade soil up to 250% in the study done by Aggarwal, Praveen and Sharma, Bajinder (2011). In a particular study, Chowdary, A.K. et. al., (2011) completed series of swelling tests & CBR tests on expansive soils for unreinforced & reinforced cases using jute geotextile and geogrid placed in different layers. Results proved that the insertion of varying number of reinforcement layers at embedment ratio (z/d) of 0.25, 0.50, 1.0 and 1.50 respectively from the top of the specimen not only controls the swell potential but also improves the CBR value significantly. Rudramurthy, M. and Vikram, M.B. (2016) carried out the laboratory tests on granular soil for different grading with and without geotextiles, in one and two layers. Test results showed that, bearing ratio of reinforced granular soil with geotextile has been increased. Similarly, Singh, H.P. and Bagra, M. (2013) used jute geotextile sheets within triaxial test samples of soil in different combinations such as 1, 2, 3 and 4 layers, which, in fact, given considerable increase in CBR value of soil. In another study, Hossain, Md. Akhtar, et. al., (2015) were performed laboratory tests to investigate the behaviour of granular soil reinforced with jute fibre at 0.5%, 1.0%, 1.5%, 2.0% by weight of the soil and also for the combination of geotextile and jute fibre. The experimental results were then studied to determine the most effective combination of geotextile and jute fibre to reinforce the granular soil.

The reinforced soil is a composite material of soil and reinforcement (which improves the resistance of soil by increasing its friction in the direction of greatest stress). By means of friction, soil transfer forces to the reinforcement built in the soil mass. The reinforcement thus develops tension when the soil mass is subjected to shear stress along the reinforcement. In the present work, the strength improvement of expansive soils, which are used as subgrade for roads were studied by introducing the geosynthetic materials. Geotextile materials (woven & nonwoven) such as HP-370, PEC and TS-50 (Tencate Geosynthetics, 2015) were used to reinforce the expansive soils to test the CBR value. These geotextile reinforcement were placed at different positions and in different layers on the soil specimen. The CBR values of the unstabilized and stabilized soils were tabulated and as well as depicted in graphs for comparison purpose.

This paper helps decision makers to select type of geosynthetic material placed at different depths for different loading conditions in the field of practical applications of major civil engineering structures such as construction of pavement, retaining structure, embankment etc.

2. MATERIALS

2.1 Soil samples

The representative soil sample is collected by excavation from the site near by the construction of Outer Ring Road (ORR) of Hyderabad city at Patancheru, Medak District, and Telangana State, India. The collected soil sample is oven dried, pulverized and sieved through different sieves as per requirement of IS standard tests given in IS 2720-part 4.(1985).Tests were conducted on the collected soil sample without reinforcement to determine the engineering properties including CBR as well as other index properties before reinforcing. The derived properties are given in the below Table1.

Table 1: Soil Properties of the study area (following IS 2720 (part 4, 5, 8., 1985)

Soil Property	Value
Gravel (up to 4.75mm) (%)	1.43
Sand (4.75 to 75micron) (%)	38.25
Silt and clay (passing 75 Micron (%)	60.32
Free swell index (%)	60
Maximum Dry density (kN/cum)	1.63
Optimum Moisture content (%)	15.5
Liquid Limit (%)	52
Plastic Limit (%)	27
Plasticity Index	25
CBR value without Geotextile (soaked)%	0.88
IS Classification	CH

2.2 Geotextiles

Expansive soil is characterized by high shrinkage and swelling properties. Because of its high swelling and shrinkage characteristics, it has been a great challenge to the highway engineers. The expansive soil is very rigid when it is in dry condition but loses its strength completely when it is in wet condition. The change in moisture content lead to failure of pavement in the form of settlements, heavy depressions, cracking and unevenness on the road surface. This poses serious problems as regards to subsequent performance of the road. Geotextiles are used in various applications to improve the strength of weak soil. These manufactured polymeric materials used for reinforcing soil material in pavement systems for both paved and unpaved roadways (Arora, K.R, 2011).

The Geotextiles are made of polypropylene, polyester, polyethylene, polyamide (nylon), polyvinyl chloride and fibre glass. Polypropylene and polyester are the most used. Selection of geotextile polymer is based on the factors such as pH of water, exposure to sunlight and ambient temperature (Koerner, Robert. M, 2012). Experience with these factors should be considered in selecting or specifying acceptable geotextile materials.

In the present work, Geotextiles materials such as HP-370 & PEC (both woven) and TS-50 (non-woven) were procured from Tencate Geosynthetics (Tencate Geosynthetics, 2015) as these are popular geosyntehtic materials available. CBR tests are conducted with these three types of soaked geotextiles (HP-370, PEC, TS-50) as shown in fig.1.

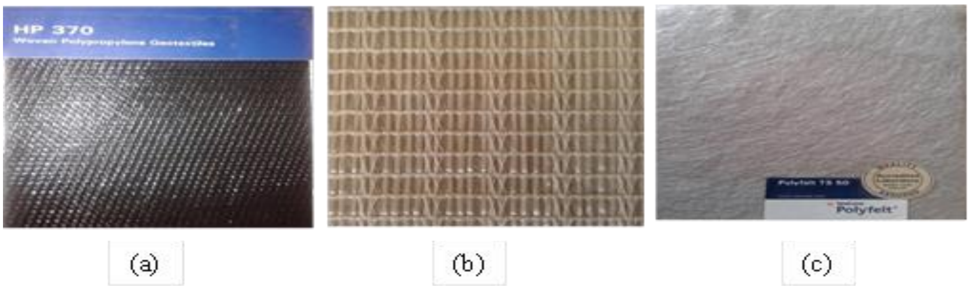

Fig1. (a).Woven Polypropylene Geotextile (HP-370) (b).Woven geotextile Poly Felt (PEC), (c).Nonwoven Geotextile (TS-50)

3. METHODOLOGY

CBR tests are conducted on selected unreinforced soil (obtained CBR of 0.88) and reinforced soil with a single layer and multiple layers of geotextiles in soaking condition. All the soil samples were prepared at Maximum Dry Density (MDD) and Optimum Moisture Content (OMC) as per IS standards (IS 2720 Part 8) and soaked CBR tests were conducted as per IS standards (IS 2720-part 16 (1985)). The CBR values of all the specimens were evaluated corresponding to both 2.5mm and 5.0mm plunger penetrations.

3.1 Placement of Geotextiles

As discussed in the introduction section, various researchers/scientists have tested the performance of their geotextile materials as reinforcement placed at different depths. They have only illustrated the importance of placing the geotextiles at known definite depths (1/4, 1/2, 3/4, 1/3 and 2/3) of the mould to achieve the better CBR value. But, there could be the possibility of gaining the best CBR when geotextiles are placed at various other depths of the mould in case of clayey soils. In the present study, the authors have attempted to find the possibility of gaining the best CBR when placing the geotextiles at various other possible depths (0.2, 0.4, 0.6 and 0.8) of the mould as discussed in the below section in two different cases.

3.2 Case-I (Single Layer Reinforcement):

In order to test the performance of each geotextile, first, the individual geotextile material is placed in the mould as single layer for chosen depths.

(i). Geotextiles placing at even distances: The soaked geotextile materials HP-370, PEC and TS-50 are placed independently as a single layer each time at 0.2H, 0.4H, 0.6H and 0.8H (from the top) of the CBR mould and tested for CBR values (H is the total height of the mould).

(ii). Geotextiles placing at uneven distances: The soaked geotextile materials HP-370, PEC and TS-50 are placed independently as a single layer each time at 0.33H, 0.5H and 0.66H of the CBR mould and tested for CBR values.

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3.3 CASE-II (Multi-layer Reinforcement):

The selected geotextiles are placed independently in two layers and three layers each time at H/3 and H/4 of the mould and tested for CBR values.

Below figure 2 demonstrates the placement of geotextiles in the mould with soil sample at different depths.

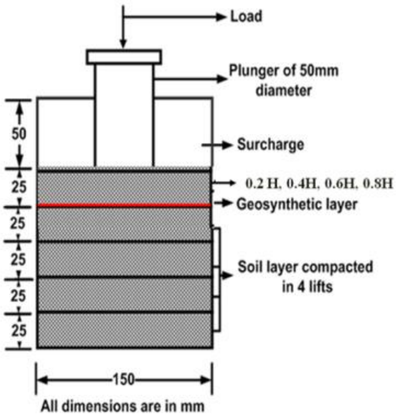

Figure 2: Placement of Geotextile in the mould (all dimensions are in mm)

4. RESULTS & DISCUSSION

The CBR tests were conducted as per the IS standards (IS 2720–part 8 (1985) on pre-reinforced soil specimen as well as reinforced soil specimens at different depths as discussed in the above section 3 with CASE-I and II.

4.1 CASE-I (Single Layer Reinforcement):

(i) Geotextiles placing at even distances:

The penetration of the plunger is observed more (which means CBR value less) for clayey soil specimen without geotextile, whereas, the same clayey soil reinforced with geotextiles have shown much better performance (with higher CBR values) in soaked condition, which have been tabulated below and represented in the following figures.

Table 2: CBR and its percentage increase for single layer of geotextile reinforcement at fixed incremental depths in soaked condition of the clayey soil (CBR without geotextile = 0.88)

Geotextile	Geotextile @ 0.2H		Geotextile @ 0.4H		Geotextile @ 0.6H		Geotextile @0.8H	
	CBR	% increase	CBR	% increase	CBR	% increase	CBR	% increase
Woven (HP-370)	1.61	83	1.46	66	1.22	38	0.91	3.4
Woven (PEC)	1.71	94	1.42	61	1.18	34	0.96	9.0
Non-woven (TS-50)	1.88	113	1.69	92	1.31	48	0.98	11.3

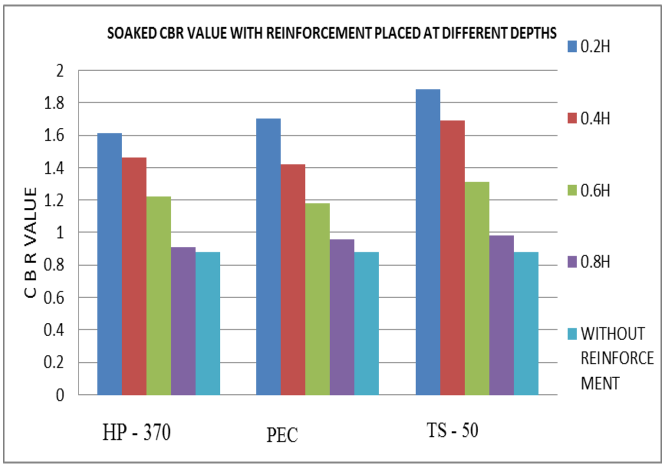

Figure 3: Bar chart variation of increase in CBR at different depths in the CBR mould

As observed from table 2, the CBR value is increased to about 1.88 for TS–50, a non-woven geotextile placed at 0.2H in the CBR mould. The percentage increase is about 113% with respect to the soil without geotextile. From the bar chart figure 3, it is further clear that the clayey soil reinforced @ 0.2H with TS–50 shows the highest increase in CBR compared to other geotextiles. All the three geotextile materials are performing better at 0.2H depth than all other depths (0.4H, 0.6H and 0.8H). They seem to be performing well when they are nearer to the surface than they are going deep into the mould.

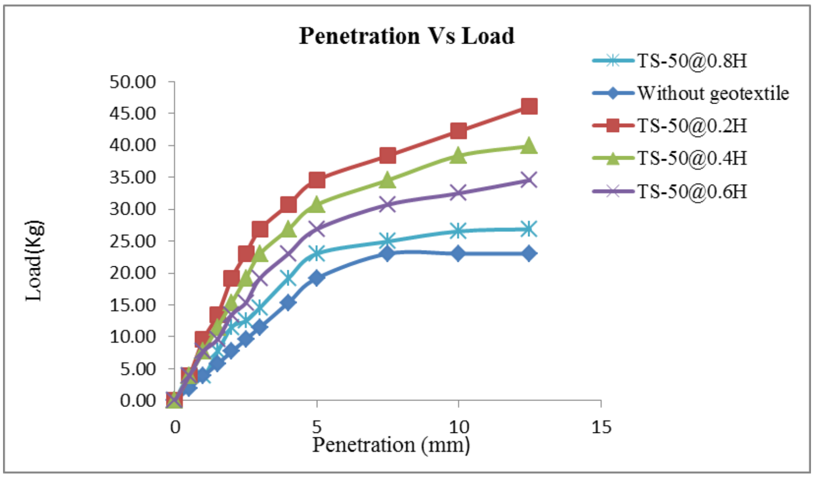

Figure 4: Variation of Load – Penetration with TS – 50 geotextile placed at different depths.

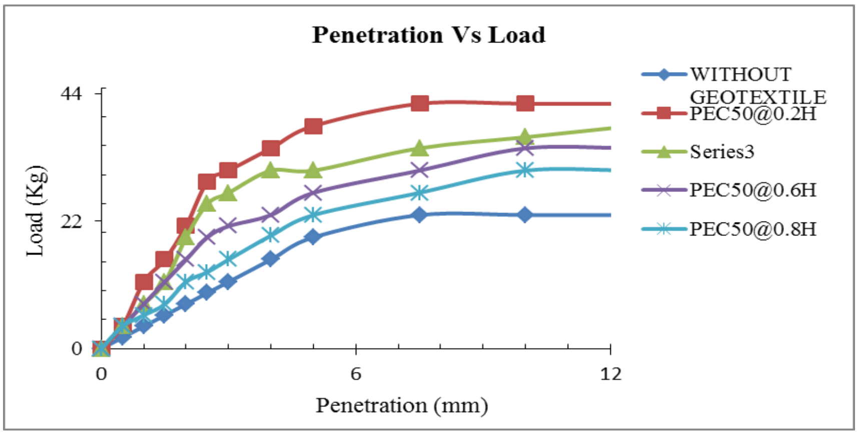

Figure 5: Variation of Load- Penetration with PEC geotextile placed at different depths (Single layer)

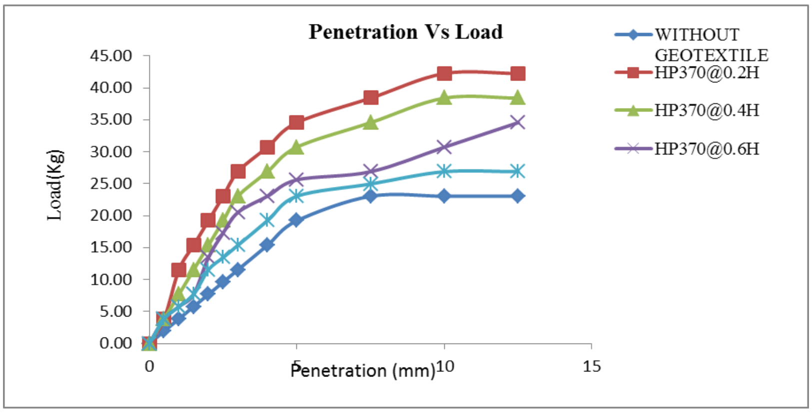

Figure 6: Variation of Load – Penetration with HP – 370 geotextile placed at different depths (single layer)

Figures 4, 5 and 6 depict the load-penetration variations for the materials TS-50, PEC and HP-370, respectively. From these figures also it is further reiterated that TS-50 is performing better than other two geotextiles as it can be seen in the figure 4, where TS-50 takes the highest load compare to other two geotextiles for the same penetration of 12 mm.

(ii) Geotextiles placing at uneven distances:

As shown in table 3 and also depicted in bar chart in figure 7, the non-woven TS-50, as it is performed well @ 0.2H, also performed well at 0.33H compared to other geotextiles (HP-370 and PEC). The CBR value is increased to about 1.61 for TS–50 geotextile placed at 0.33H in the CBR mould and the corresponding % increase is 83%. After TS-50, PEC seems to be performing well at these depths and HP-370 is the least. As observed previously, these geotextiles are performing better at the nearer to the surface rather than at more depth into the mould.Figures 8, 9 and 10 are the load vs penetration curves at the depths of 0.33H, 0.5H and 0.66H, for the HP-370, PEC and TS-50 geotextiles respectively. From these figures, it can be observed that TS-50 takes the maximum load of more than 40 Kg compared to other materials at 0.33H and this being the highest even when comparison done with @ 0.5H and 0.66H depths.

4.2 CASE-II (Multi-layer Reinforcement):

As discussed earlier, all the three geotextiles were also placed in two layers and three layers, separately, at selected depths to test their independent performance. Accordingly, geotextiles were placed in two layers at H/3 depth and three layers at H/4 depth of the CBR mould (from top) using the same clayey soil. CBR values and the obtained results are tabulated in table 4 and corresponding bar chart is depicted in figure 11.

Table 3: CBR and its percentage increase for single layer of geotextile reinforcement at variable depths in soaked condition of the clayey soil (CBR without geotextile = 0.88)

Geotextile	Geotextile @ 0.33H		Geotextile @ 0.5H		Geotextile @ 0.66H	
	CBR	% increase	CBR	% increase	CBR	% increase
Woven (HP-370)	1.32	50	1.38	57	1.16	32
Woven (PEC)	1.34	52	1.42	61	1.26	43
Non-woven (TS-50)	1.61	83	1.58	79	1.3	48

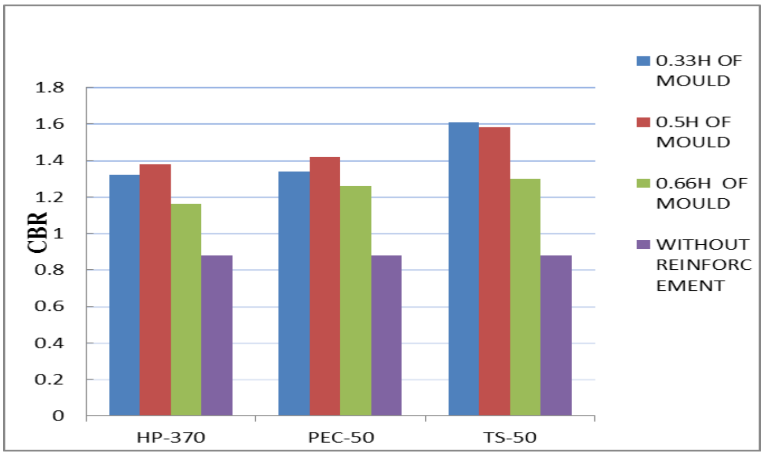

Figure 7: Variation of CBR value with placed at depth of 0.33H and 0.66H bar chart

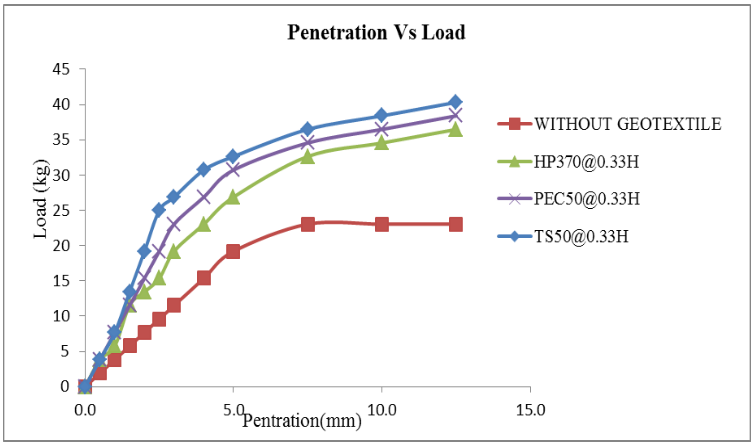

Figure 8: Variation of Load – penetration of clayey soil with reinforcement at 0.33H of mould

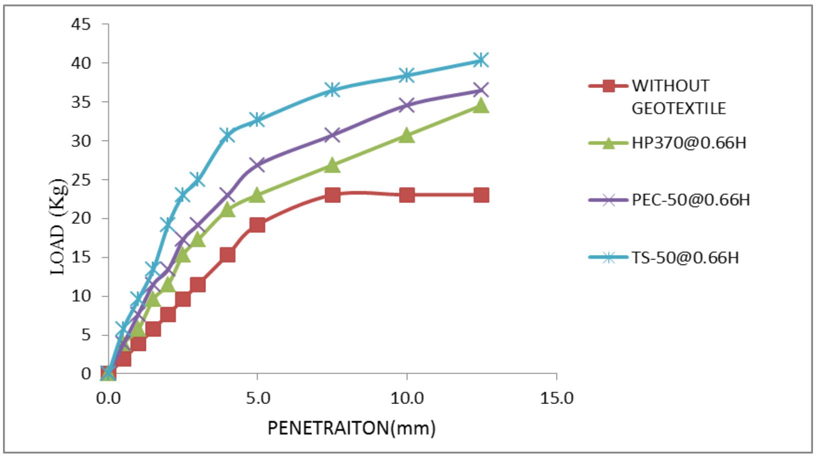

Figure 9: Variation of Load – penetration of clayey soil with reinforcement at 0.5H of mould

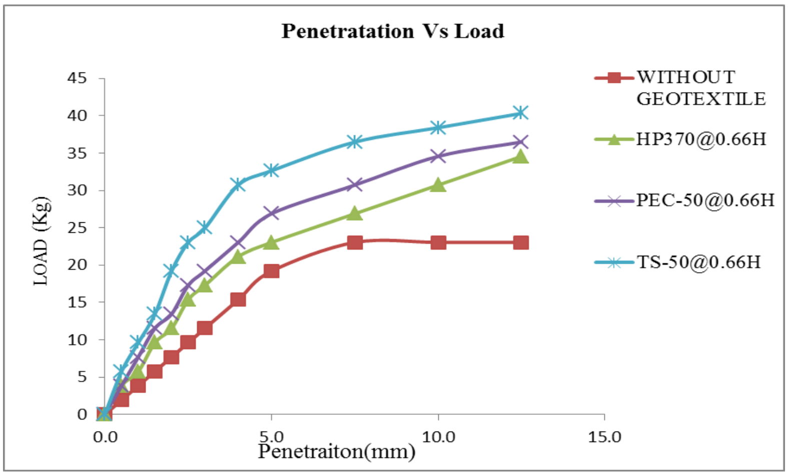

Figure 10: Variation of Load – penetration of clayey soil with 3 types of textile placed at 0.66H of mould:

Table 4: CBR and its percentage increase for multilayer geotextile reinforcement in soaked condition of the clayey soil at different depths (CBR without geotextile = 0.88)

Geotextile	2 Layers of Geotextile		3 Layers Of Geotextile	
	CBR @H/3	% increase	CBR @H/4	% increase
Woven (HP-370)	2.24	154	2.61	196
Woven (PEC)	2.8	218	2.8	218
Non-woven (TS-50)	2.9	229	3.92	345

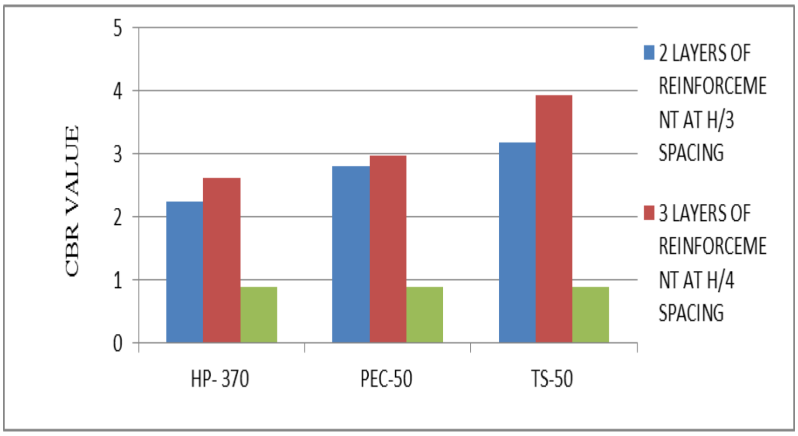

Figure 11: Variation of CBR with 2 and 3 layers of geotextile reinforcement placed at H/3and H/4

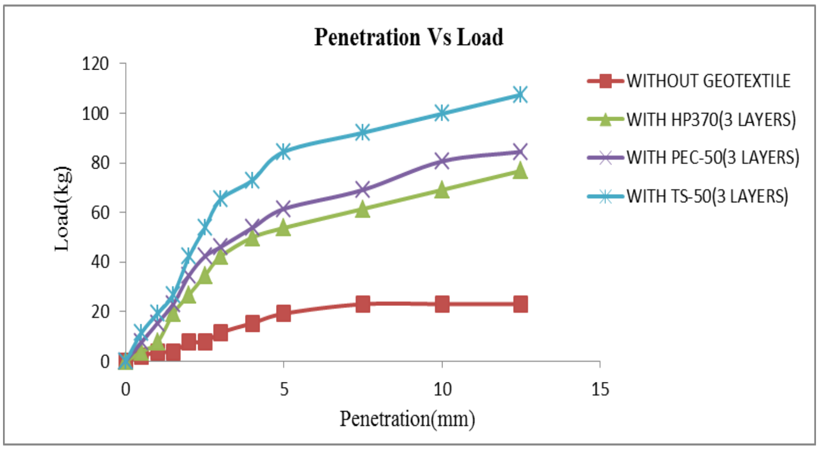

Figure 12: Variation of Load – penetration of clayey soil with reinforcement placed in 3 layers at H/4 in the CBR mould.

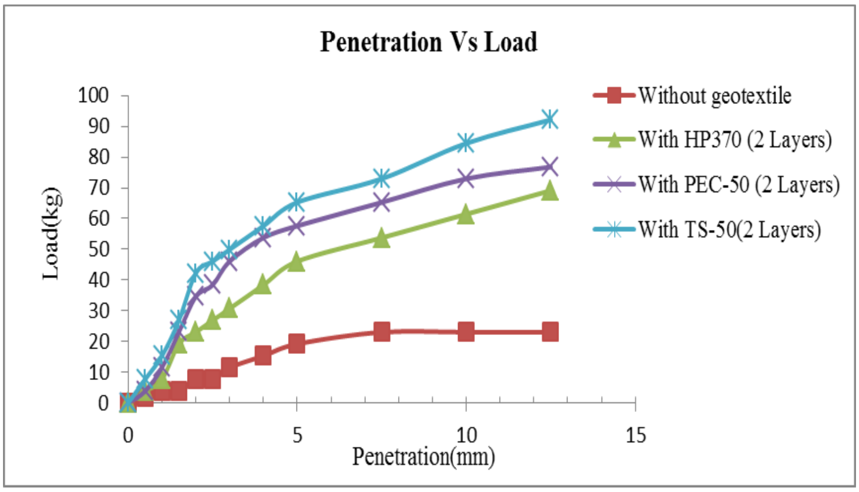

Figure 13:Variation of Load – penetration of clayey soil with reinforcement placed in 2 layers at H/3 spacing

Table 4 and figure 11 illustrates that again TS-50 performed very well among all other geotextiles. Between H/3 and H/4 depths, geotextiles placing at H/4 depth would perform well than placing at H/3 depth. As it can be observed from the results that TS-50 could give the CBR value of 3.92 at H/4 depth and corresponding percentage increase of 345% which is the highest of all the attained CBR values in the present work. Next better performer is the PEC which could give CBR value of 2.8 and corresponding increase is 218% at both the depths.

Figures 12 and 13 depict load vs penetration of the two layers and three layers placed at H/3 depth and H/4 depth of mould, correspondingly. TS-50 placed at H/4 depth with three layers taken maximum load of more than 100 Kg for the same penetration of 12mm compared to other geotextiles at the same depth. Similarly, TS-50 also could take maximum load of 90 Kg for the penetration of 12mm with two layers placed at H/3 depth of the CBR mould.

Overall, TS-50 could perform very well in comparison to other two geotextiles HP-370 and PEC of the Tencate Geosynthetics. Following conclusions are drawn from the present study.

5. CONCLUSIONS

A series of CBR tests are conducted to investigate the effect of geotextile placed at different depths and in different layers on the clayey soil. The major conclusions obtained from this study are as follows:

i. The CBR values of the subgrade clayey soil of ORR, Hyderabad city, can be improved by placing the selected soaked geotextiles (namely, TS-50, PEC and HP-370) at various depths in the CBR mould.

ii. In Case-I of single layer reinforcement, among all geotextiles placed at even distances independently, TS-50 placed at 0.2H could give the best CBR value of 1.88 with 113% increase compare to pre-reinforcement soil in the study. The next geotextile is the PEC could give better CBR values at the same depth of 0.2H.

iii. In connection with above (ii), it is observed that, as the placement of the geotextiles is deeper in the CBR mould, their performance is becoming poorer. In another sense, placing the geotextiles nearer to the surface of CBR mould could give best CBR values compare to other depths.

iv. In Case-I of single layer reinforcement, among all geotextiles placed at uneven distances independently, TS-50 placed at 0.33H could give the best CBR value of 1.61 with 83% increase compare to pre-reinforcement soil in the study. The next better geotextile is the PEC which could give CBR value of 1.42 @ 0.5H after TS-50 with CBR value of 1.58.

v. In connection with above (iv), it is observed that TS-50 performance was becoming lesser as its placement is increased in depth of the CBR mould whereas other two (HP370 and PEC) were different. At 0.5H, their performance improved little but again performed poorly at lower depth of 0.66H.

vi. In case-II of multi-layer reinforcement, again TS-50 could give best CBR results compared to other geotextiles. Especially, TS-50 with 3 layers placed H/4 depth of the mould was the best in all of the experimental analysis of the present study. The CBR value is 3.92 with 345% increase compared to pre-reinforced soil of the study area. The next better geotextiles is the PEC which could give only 2.8 at the same depth. As against with three layers of reinforcement, two layers reinforcement was poorer at H/3 depth of the testing mould.

vii. In overall, the TS-50 (Non-woven) can be named as best geotextile, both in single layer reinforcement as well as in multi-layer reinforcement. TS-50 could give the highest CBR values when it is placed nearer to the surface of the mould compare to deep into the mould.

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