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3rd International Conference on Road and Rail Infrastructure
28–30 April 2014, Split, Croatia

Road and Rail Infrastructure III

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INFLUENCE OF LAYERED GEOSYNTHETICS ON CBR OF CLAYEY SUBGRADE WITH SOIL-GEOSYNTHETIC INTERACTION

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Abstract

The present research focuses on improvement of various soil properties and strength parameters of clayey subgrade using geogrid (biaxial) and geotextile (nonwoven) placed through various reinforcement systems viz. Single layer reinforcement system (SIL), composite layer reinforcement system (COL), multi layer reinforcement system(ML) at various position/levels of subgrade thickness. A high strength geotextile and a biaxial geogrid are used as geosynthetic reinforcement materials in this study. Soaked and Unsoaked CBR tests were performed on expansive soil (CI and CH soil) using above mentioned reinforcement systems. The main objective of this study is to know the most efficient geosynthetic reinforcement system and position of reinforcement for medium expansive soil (CI) and highly expansive soil (CH) of Gujarat region.. Given results depicts that infusion of geosynthetic reinforcement at various levels of subgrade note only improves CBR value but overall its increases the structural stability of the subgrade. Out of various subgrade systems composite reinforced system at position of h/5 gave the maximum CBR value and its calibration with modulus of subgrade reaction (K) was quite compatible.

Keywords: subgrade, geosynthetics, reinforcements, expansive soils, CBR value

1 Introduction

Pavement is a durable surface having materials laid down on an area subjected to sustain mainly the vehicular traffic, such as a road or highway. Subgrade is the foundation layer; the structure must eventually support all the loads which come on to the pavement. The performance of the pavement is affected by the characteristics of the sub-grade. Desirable properties which the sub-grade should possess are: strength, ease of compaction, permanency of compaction and permanency of strength, low susceptibility to volume changes and frost action. Since sub-grade soils vary considerably, the inter-relationship of texture, density, moisture content and strength of sub-grade materials includes maximum dry density (MDD), optimum moisture content (OMC), CBR and E-value of sub-grade material. To understand the behavior of failure and minimize it, a compressive laboratory program was made to study the strength characteristics of both reinforced and un-reinforced soil. This work describes the beneficial effects of reinforcing the sub-grade layer made up of expansive soil (CH & CI) with either single, double or multiple alternate layers of geo-grid and geotextile at different positions to determine the optimum position based on CBR test values.

1.1 Theoretical developments

The concept of reinforcement is not new. Early civilizations commonly used sun-dried soil bricks as a building material. And in their experience it became an accepted practice to mix the soil with some kind of fiber to improve the properties (Dean, 1986)[1]. The materials used as reinforcement in sub-grade soil can vary greatly, either in form (strips, sheets, grids, bars, or fibers), texture (rough or smooth), and relative stiffness. Nejad and Small (1966)[2] investigated that geogrid could significantly decrease the permanent deformation in the pavement by 40% to 70%. Ling and Liu (2001)[3] carried out some static and dynamic tests on model sections to find out the contributions of geosynthetic reinforcement to the stiffness and strength of asphalt pavements. The study showed that the settlement over the loaded area of reinforced pavement as reduced when compared with un-reinforced pavement. Also C.R. Lawson (1995)[4], Asha (2010)[5], M.S. Natraj (1997)[6], Minu Michal (2009)[7], they all studied about geosynthetic as reinforcement.

1.2 Laboratory investigations

Soil collected from Kheda region and Sanand Region of Gujarat State has been used as subgrade material in the experiments. The soil is classified as CI and CH. Index properties are found out in the laboratory. The properties of the soil used in the study are given in Table 1. Geosynthetic material was carried from TECHFAB INDIA and also property of goetextile and geogrid as in Table 2 and Table 3 geogrid and geotextile respectively.

1.3 Testing methodology

California Bearing Ratio tests were conducted on CI and CH soils, unreinforced and reinforced with a single layer and double layers of geotextiles or geogrids and either composite layer of geogrids & geotextile.To reinforced a sample, composite material of geogrids & geotextile were placed in a single layer at different positions: h/2, h/3 & h/5 & multi layer of geogrids & geotextile were placed at h/3 & h/6 of the specimen height from the top surface. The dry weight required for filling the mould was calculated based upon the maximum dry density(MDD) and corresponding optimum moisture content was achieve from standard proctor test. A total of 15 samples of reinforced and unreinforced both unsoaked were tested (as per IS 2720-16)[4] the load penetration readings were noted for all the samples to obtain CBR value, modulus of subgrade reaction (K) and secant modulus.

Table 1 Physical properties and classification

Index Properties	Kheda Region	Sanand Region
Liquid Limit (L_L)	35.75%	66.30%
Plastic Limit (P_L)	19.09%	23%
Soil Classification	CI	CH
Optimum Moisture Content (OMC)	21.70%	22.55%
Max. Dry Density (MDD)	1.60 gm/cc	1.645 gm/cc
Specific Gravity	2.59	2.60

Table 2 Properties of Geogrid

Sr. No	Experiment Work		ASTM Code	Biaxial geogrid
1	Ultimate tensile strength (KN/m)	MD	D-6637	90
		CD		90
2	Elongation at maximum load (%)	MD		15
		CD	D-6637	15
3	Tensile strength at 2% elongation (KN/m)	MD		11
		CD		9
4	Tensile strength at 5% elongation (KN/m)	MD	D-6637	21
		CD		
5	Aperture Size (±2mm)	MD X CD		23x23

Table 3 Properties of Geotextiles

Sr. No	Experiment work	ASTM Code	Unit	Nonwoven geotextiles
1	Mass per unit area	D-5261	g/m^2	200
2	Grab Tensile strength	D-4632	N	720
3	Elongation @ break	D-4632	%	60
4	Trapezoidal Tear	D-4533	N	300
5	Puncture Strength	D-4833	N	400
6	Permeability/ Flow rate	D-4491	$l/m^2/s$	100
7	Mullet Burst	D3786	kPa	2175
8	Thickness	D-5199	mm	1.6
9	Apparent Opening Size	D-4751	μm	150

2 Plots for Comparison

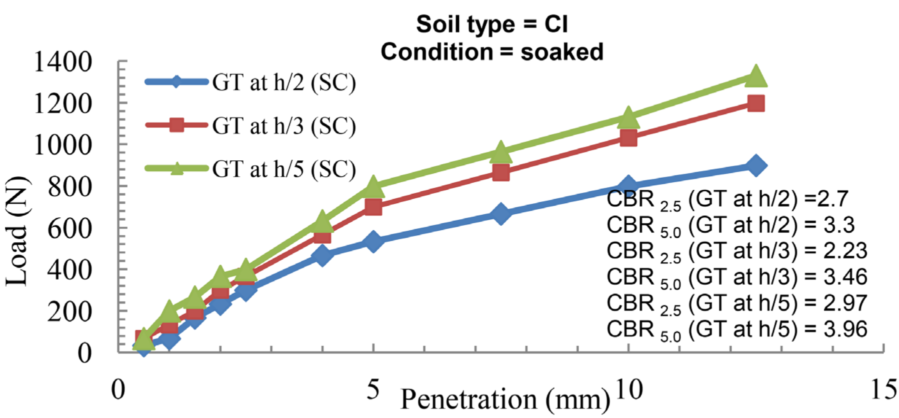

Figure 1 Load v/s penetration curve for SIL of GT at different position (SC)

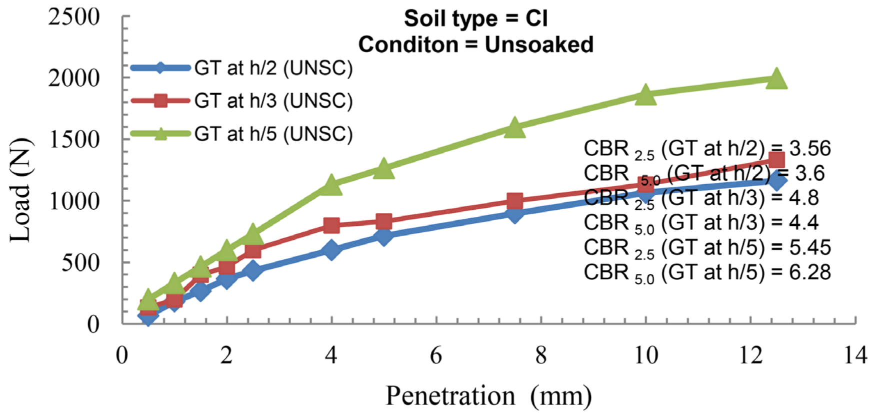

Figure 2 Load v/s penetration curve for SIL of GT at different position (UNSC)

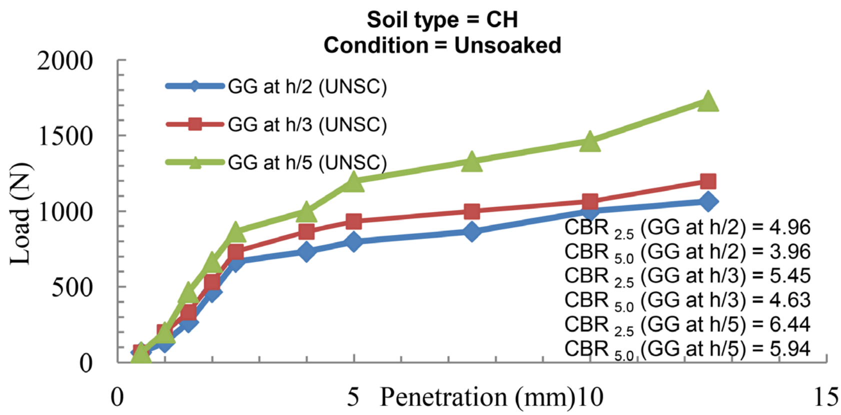

Figure 3 Load v/s penetration curve for SIL of GG at different position (UNSC)

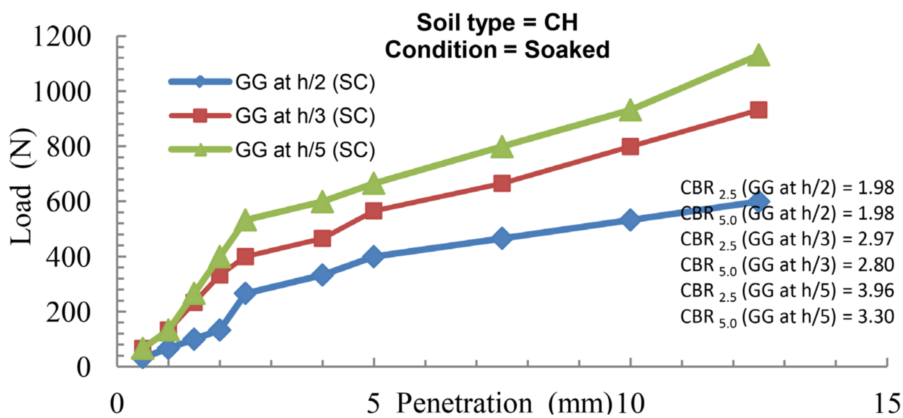

Figure 4 Load v/s penetration curve for SIL of GG at different position (SC)

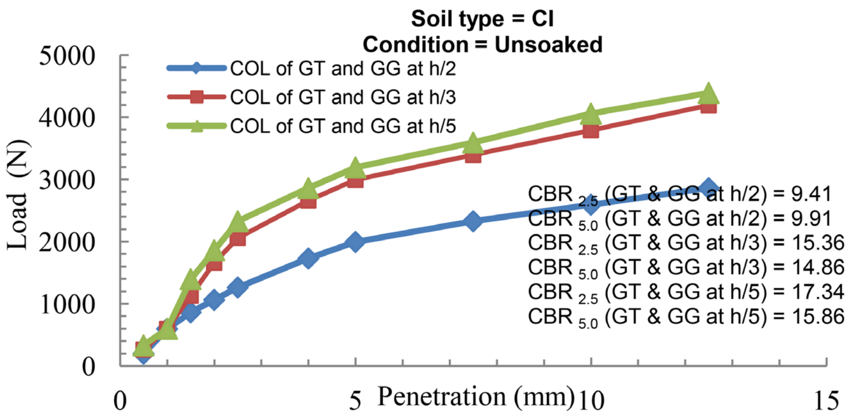

Figure 5 Load v/s penetration curve for COL for various positions of GG and GT

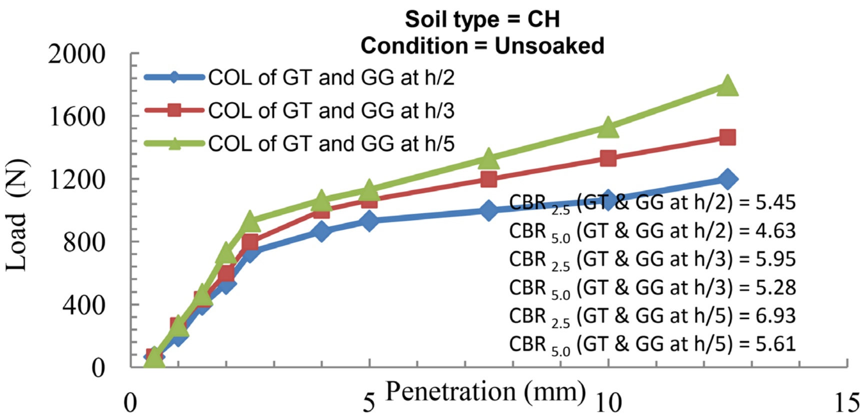

Figure 6 Load v/s penetration curve for COL for various positions of GG and GT

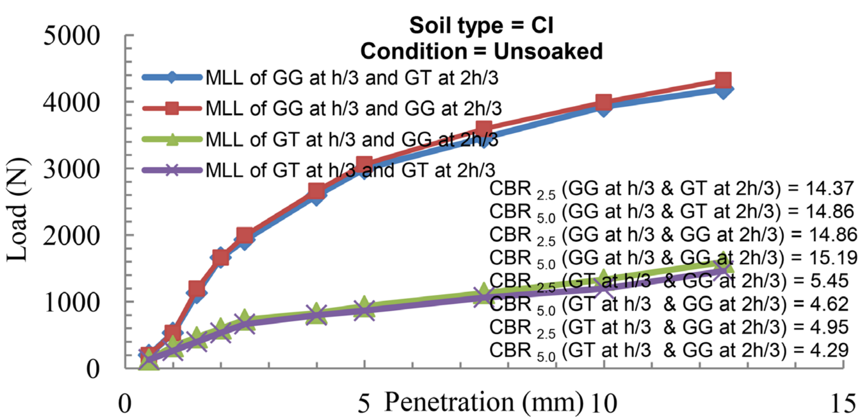

Figure 7 Load v/s penetration curve for MLL for various positions of GT and GG

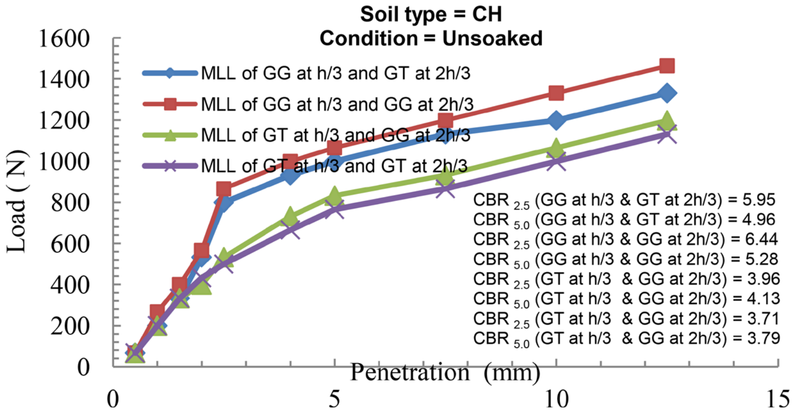

Figure 8 Load v/s penetrations for MLL for various positions of GT and GG

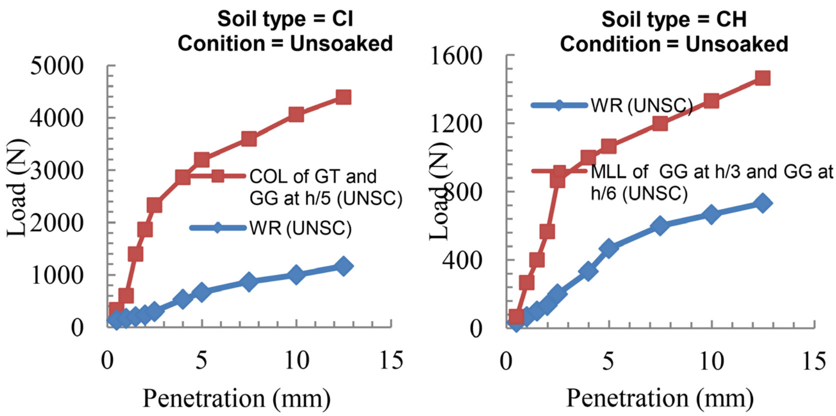

Figure 9 Load v/s penetration curve for comparison of WR with COL and WR with MLL for GT and GG at h/5 (UNSC)

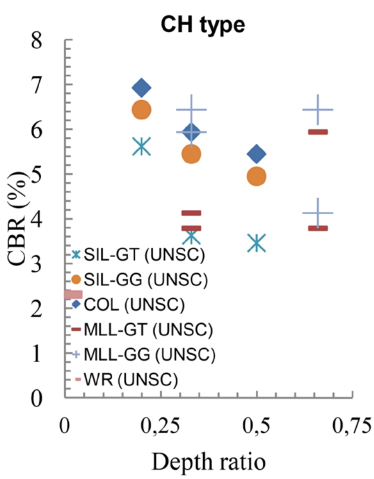

Figure 10 Comparison of CBR v/s depth ratios for WR, SIL, COL and MLL

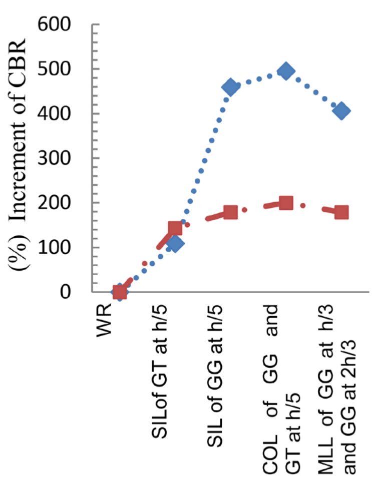

Figure 11 Percentage increment of CBR v/s various efficient reinforcement systems

3 Results, analysis and discussion

The relative performance of various geosynthetic reinforcement systems in terms of CBR value and its interaction with subgrade is discussed below.

3.1 Effect of single layer of geotextile (GT) and Geogrid (GG) at various locations

From figures 1, 2, 3, and 4 it is observed that geotextile placed at h/5 shows more load carrying capacity compare to h/3 and h/2 under soaked and unsoaked condition. From the plot it is reflected that load carrying capacity of geotextile at h/5 is nearly 1.1-1.5 times to h/3 and h/2 at same penetration of 5mm and 10mm under soaked condition and 1.5 – 1.8 times to h/3 and h/2 under unsoaked condition. In case of CI soil Geogrid placed at h/5 shows more load carrying capacity compare to h/3 and h/2 under soaked condition while under unsoaked condition geogrid is effective both at h/5 and h/3. From the plot it is reflected that load carrying capacity of geogrid at h/5 is nearly 2-2.5 times to h/3 and h/2 at same penetration of 5mm and 10mm under soaked condition while load carrying capacity remains almost same at h/5 and h/3 under unsoaked condition. While in case of CH soil geogrid placed at h/5 shows more load carrying capacity compare to h/3 and h/2 under soaked condition while under unsoaked condition geogrid is effective both at h/5 and h/3. From the plot it is reflected that load carrying capacity of geogrid at h/5 is nearly 1.1-1.7 times to h/3 and h/2 at same penetration of 5mm and 10mm under soaked condition while load carrying capacity remains almost same at h/5 and h/3 under unsoaked condition.

3.2 Effect of combined layer of geotextile (GT) and Geogrid (GG) at various locations

From Fig 5, and 6, it is observed that combined composite layer of geogrid and geotextile placed at h/5 shows more penetration compared to h/3 and h/2 under both soaked and unsoaked condition for both types of soil i.e. CI & CH. From the plot it is clear that the nature of curve is quite linear in case of CH soil when composite reinforcement placed at h/5, while some curvature is seen for h/3 and h/2 for CI type of soil. Curve of h/5 remains above curve of h/2 and h/3 both under initial and final penetration. From the plot it is also observed that load carrying capacity of combined reinforced mass at h/5 is nearly 1.25-1.7 times to h/3 and h/2 at same penetration of 5 mm and 10 mm under soaked and unsoaked condition. Resistance to penetration is observed for initial loads when composite reinforcement placed at h/5 indicating the superimposed layer of geotextile on geogrid offers more resistance because of its high interface friction, more compression capacity and high strain compatibility. More load carrying capacity with less penetration is observed in case of CH soil at initial level up to 5 mm but thereafter in increases linearly showing constant amount of penetration with increasing trend as compared to decreasing trend seen in CI soil.

3.3 Effect of multi-layered composite layer of geotextile (GT) and geogrid (GG) at various locations

From fig 7 & 8, it is observed that multi layer reinforcement (one layer of geogrid and one layer of geotextile) placed at h/3 shows more penetration compared to h/3 under unsoaked condition for both CI and Ch soils. Four combinations of multi layered system were tested using CI and CH soil in following way: GT at h/3 & GG at h/6, GG at h/3 & GT at h/6, GG at h/3 & GG at h/6, GT at h/3 & GT at h/6 respectively. Combination of GG at h/3 & GG at h/6 shows maximum load carrying capacity at 5mm and 10mm penetration compare to other while combination of GG at h/3 & GT at h/6 showed better results compared to others. It is also noted that initial nature of curve for all combinations is same except in case of GT at h/3 & GT at 2h/3 which is quite distinct showing very less value of load carrying capacity both at 5mm and 10mm penetration. Curves almost remain linear during initial period of load showing less penetration compare to geotextile which in other words can be said that geogrid offers more resistance to penetration under 5mm and 10mm. Curve of h/3 remains above curve of 2h/3 both under initial penetration and final penetration. Resistance to penetration is observed for initial loads when geogrid placed at h/3 and at 2h/3 indicating that biaxial geogrid placed near to surface offers more resistance because of its high tension capacity, more interlocking friction and rigid strain compatibility (more resistance to deformation). Also cross plane (lateral) resistance to load is much more compare to geotextile. Here also as we move away from surface (load area) effect of reinforcing soil decreases.

3.4 Effect of WR and various reinforcement systems under various conditions

Referring to figure 9 showing the comparison of load vs. Penetration plots between unreinforced soil (WR) and single layer reinforced soil (SIL) with geotextile (GT) at h/5 for CI and CH soil, we can conclude that for unsoaked condition load carrying capacity is more compared to soaked condition and with infusion of single layer geotextile load carrying capacity increases rapidly both at 2.5mm and 5mm penetration. For COL with geotextile (GT) and geogrid (GG) at h/5 for CI and CH soil the nature of plot is quite similar both in case of CI and CH soil i.e. very narrow increasing trend in load with more deformation. Multi layer reinforcement system is more beneficial as higher resistance is offered by reinforcement against shearing phenomena of CI soil particles as both layers of geogrid are offering tenacity, shear resistance and lateral spreading of soil.

3.5 Comparison of CBR for WR and various reinforcement systems under various conditions

Referring to figure 10 & 11, showing comparison of composite reinforcement and multi-layered system reinforcement it is very clear that multi-layered system reinforcement is more advantageous as compared to composite system. Hence it can be said that location of reinforcement is playing a vital role CBR value or we can say that CBR value is related to the location of reinforcement particularly in case of expansive soils. In case of composite reinforcement for CI & CH soil, location of reinforcement at h/5 shows maximum CBR value of 17.35% and 6.3 % respectively, while if we compare layered reinforcement system then combination of GG at h/3 & GG at h/6 shows increment of CBR value of 15.2% for CI soil and 6.44% for CH soil under unsoaked condition. Referring to fig 9 which shows increment of CBR value for composite and multi-layered system, it is very clear that composite system shows nearly 480% more CBR value for CI soil while 200% more CBR value for CH soil and in case of multi-layered system it shows 396 % for CI and 179% for CH soil respectively. This concludes that under unsoaked condition, composite geogrid shows better results and is more efficacious at location h/5. On comparing CBR results of reinforced soil using MLL of GG at h/3 & GG at 2h/3 and GT at h/3 & GG at 2h/3 separately the CBR value increases from 178% and 56% for CI and CH soil. Very peculiar phenomena was observed in case of CBR samples interfaced with geogrid, that as load increases from zero to 50kg penetration value is very less, just 2mm it means much of load is occupied as seating load and because of high rigidity of MLL, GG at h/3 & GG at 2h/3 of, almost interfaced soil layer would get compressed to same amount to occupy aperture size or geogrid superimposing with soil layer, while in case of geotextile at 50kg load penetration was almost nearly 44mm double to that of geogrid which indicated that as geotextile fiber is soft enough that compression of soil sample along with compression of geotextile is such that at interface, tension is developed between partile-to-partile along with bearing capacity failure at the end is noted. In case of geogrid sliding failure is observed at the end of test. Computing modulus of subgrade reaction (K) from CBR value it is observed that value are within acceptable limits and higher k value s observed for geogrid at h/5 as shown in table 4.

Table 4 Comparison of CBR Value and modulus of subgrade

Location		CBR [%]	K-value [kg/cm²]
GG @ h/5	Composite (CI)	17.35	6.51
GT @ h/5	Composite (CH)	6.93	4.81
GG @ h/3 & h/6	Multi-layered (CI)	15.2	6.23
GG @ h/3 & h/6	Multi-layered (CH)	6.44	4.64

4 Conclusions

The following major conclusions drawn from this study:
- Improvement of clayey subgrade by using any geosynthetic reinforcement system yields gain in CBR value as compared to unreinforced troublesome expansive soil.
- Reinforced subgrade soil system performs better than unreinforced in terms of CBR value increment and reduction in penetration at specific load.
- Composite reinforcement system shows better and reliable results as compared to multi-0layered system both for CI and CH soils. Location of geosynthetics at particular height of subgrade and its interaction with soil under various loads plays a vital role in predicting failure mechanism of subgrade.
- Highest CBR value is achieved with subgrade reinforced with geogrid at location h/5 for given OMC and densification. While in case of multi-layered system GG ath/6 and GG at h/3 showed maximum CBR value under unsoaked condition.
- Modulus of subgrade reaction (k) value is much nearer to standard range and can equally be applied for settlement predictions and design of pavements.
- Design of clayey subgrade using geosynthetic reinforced systems in terms of relative efficiency of various reinforcement systems at various positions of subgrade and their effect on the load-penetration behavior.

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