



Research Article

Optimization of geogrid reinforcement for improving CBR of subgrade soils

M. Bharath CHANDRA¹, Kadali SRINIVAS¹, V. Ramya KRISHNA^{1,*}

¹Department of Civil Engineering, VNR Vignana Jyothi Institute of Engineering and Technology, Hyderabad, 500118, India

ARTICLE INFO

Article history

Received: 22 March 2025

Revised: 12 April 2025

Accepted: 05 May 2025

Keywords:

California Bearing Ratio;
Geogrid Reinforcement;
HDPE Geogrid; Liquid Limit;
Maximum Dry Density;
Optimum Moisture Content;
Subgrade Soil

ABSTRACT

Weak subgrade soils can adversely affect pavement performance by reducing the load-bearing capacity of the foundation and increasing the possibility of deformation under traffic loading. This study investigates the use of geogrid reinforcement for improving the California Bearing Ratio (CBR) of different subgrade soils. Sixteen soil samples representing highly compressible clay, intermediate compressible clay, low compressible clay, and sandy soils were examined. Natural and synthetic geogrids, including coir, jute, rubber coir, polyester, biaxial polypropylene, biaxial geogrid, and HDPE geogrids, were evaluated at different depths within the CBR mould. The influence of the optimum moisture content, maximum dry density and liquid limit on the reinforced and unreinforced CBR values was also examined. The results show that geogrid reinforcement generally improves the CBR of the tested soils, although the extent of improvement varies with the soil type, reinforcement material, and placement depth. A placement depth of 0.8h produced considerable improvement for several soil samples. The highest CBR value of 12.8% was obtained for sandy soil reinforced with HDPE geogrid at a depth of 0.8h. The study also indicates that higher maximum dry density is generally associated with improved CBR, whereas excessive moisture can reduce soil strength. The findings demonstrate that selecting the appropriate geogrid and its placement depth can improve subgrade performance and may contribute to more economical pavement construction.

Cite this article as: Chandra MB, Srinivas K, Krishna VR. Optimization of geogrid reinforcement for improving CBR of subgrade soils. Sigma J Eng Nat Sci 2026;44(4):2952–2962.

INTRODUCTION

The subgrade forms the foundation of a road or pavement system and supports the layers placed above it, including the subbase and base. The subgrade's condition has a direct influence on the performance and service life of the pavement. Therefore, the subgrade needs adequate strength, bearing capacity, and stability to withstand traffic loads as

well as changes caused by weather and environmental conditions [1]. Problems in the subgrade can develop because of poor compaction, inadequate drainage, weak soil, variations in moisture content, or excessive moisture [2, 3]. These conditions may eventually result in pavement defects such as cracking, potholes, and surface erosion [4]. Identifying the factors responsible for subgrade failure is therefore

*Corresponding author.

*E-mail address: ramykrishna_v@vnrvjiet.in

This paper was recommended for publication in revised form by
Editor-in-Chief Ahmet Selim Dalkilic



important for selecting suitable remedial measures and reducing the possibility of similar failures in the future [5]. There are several ways to increase the strength and stability of the subgrade to avoid failure, namely mechanical stabilization and chemical stabilization [6]. One of the studies explains the combination of fly ash and lime that has the ability to enhance the mechanical properties of weak soil, such as kaolin soil. [7, 8]. Even the by-product of cutting and polishing of stone slabs, called rock sludge dust, is used in the construction of low-volume roads [9, 10]. One of the non-biodegradable materials, like waste plastic sheets, is also employed to improve the CBR% of the weak soils [11, 12]. The incorporation of Autoclaved aerated concrete powder, a lightweight and porous waste material, improved the workability of several clayey soils [13, 14]. However, each of these methods is associated with some limitations, such as soil compatibility, environmental impact, cost, material availability, and equipment transportation [15]. To minimize these limitations, an alternative method is adopted and it is geogrid reinforcement, which is a highly effective technique used to enhance the performance and stability of subgrade layers in pavement and road construction [16, 17]. Geogrids are polymer materials consisting of a connected mesh-like structure, which reinforces the subgrade soil. To achieve better pavement performance, geogrids are used, as they improve the load-carrying capacity of subgrade [18]. Reinforcing the soil helps distribute the applied loads over a wider area, reduce deformation, and improve the stability and tensile resistance of the subgrade [19]. Even geogrids are combined with geotextiles to improve the subgrade strength [20], and combining the geogrid and polypropylene fibres significantly increases the shear strength of expansive subgrades [21]. If the subgrade strength is low, then road pavement failure occurs [22]. To find the strength of the subgrade soil, the most common method used is the CBR test. CBR test measures the soil's resistance to penetration under a standard load [23]. Achieving a subgrade with a CBR of at least 10 is essential,

as values below this can cause deformation and deterioration of the subbase under traffic loads [24]. The stability of the subgrade is improved by geogrid reinforcement, which increases the CBR value, and they are highly versatile & can be easily installed in any weather [25, 26]. The previous studies that involved the use of geogrid in improving the CBR% and shear strength of subgrade soils were limited to only one type of soil study, with the placement of geogrid at the optimum position. Previous research has also not explained the compatibility of the type of geogrid with the particular soil and how the soil properties will affect the CBR%.

The main objective of the study is to find the compatibility of various types of geogrids for specific soil types. For this, 16 soil samples were analysed and classified according to their compressibility. The soil samples considered for this study are highly compressible clay (CH), Intermediate compressible clay (CI), Low compressible clay (CL), Silty sand, and sandy soils. Different types of geogrids were used for reinforcing the above soil samples. The application of various geogrid types in reinforcing the soil samples resulted in an exceptional 498% increase in CBR that is observed in the case of sandy soils reinforced with HDPE geogrid at a depth of 0.8h, far exceeding the 50–200% improvements documented in previous studies. These results indicate that geogrid reinforcement can provide an effective approach for improving weak subgrade soils. The findings may also support the development of more practical and economical soil reinforcement methods for future geotechnical engineering applications.

The bubble map provided in Figure 1 visualizes the contribution of different countries across the globe regarding geogrid reinforcement to enhance subgrade strength studies. This map features countries like India, the United States, China, Australia, Japan, the United Kingdom, and many others. The countries with more research work in the present area are represented in large bubbles, and the countries with smaller bubbles represent that their contributions to this study are limited.

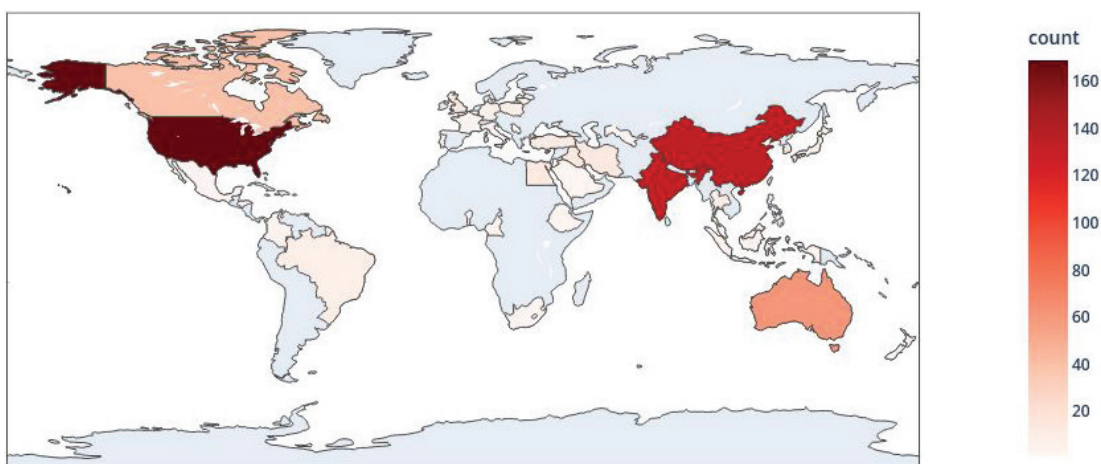


Figure 1. Pictorial representation of subgrade strength studies across various countries.

MATERIALS AND METHODS

Soils

To investigate the engineering behaviour and variation of CBR% of various soils, sixteen soil samples designated as S1 to S16 from different regions were used for this study. The locations of the soil samples that were taken are shown in Table 1. Soil properties such as MDD, OMC, and LL were

determined through laboratory tests. The samples were categorized based on their LL. $LL > 50\%$ is classified as highly compressible clays (CH), $50\% > LL > 35\%$ as intermediate compressible clays (CI), and $LL < 35\%$ as low compressible clays (CL). The classification and detailed properties are presented in Table 2.

Geogrid Reinforcement

In the present study, two categories of geogrids are used. One is natural geogrids, and the other is synthetic geogrids. Natural geogrids are bio-based reinforcement materials that are made up of organic and biodegradable fibers such as coir, jute, etc. Synthetic geogrids are made from polymeric materials such as polypropylene, polyester, etc. The features and performance of these geogrids are given in Table 3.

To analyse the optimum depth of geogrid placement in the CBR mold and to identify the most suitable geogrid for reinforcing the particular soil sample, natural, welded, and extruded geogrids were utilized to enhance the CBR% in the analysis. The geogrids used to reinforce the respective soils, along with their tensile strength, are presented in Table 4.

Sixteen soil samples were considered and distributed based on their liquid limit and compressibility. So, the soils are divided into highly compressible clays (S1 to S4), intermediate compressible clays (S5 to S10), low compressible clays (S11 to S14), and sandy soil (S15 to S16) categories. The soil samples are distributed in such a way that every geogrid that falls under synthetic and natural materials is used in all 4 classified soil samples.

For CH soils with low CBR, high-strength geogrids were required, such as polyester (200kN/m) and polypropylene

Table 1. Locations of the soil samples

Soil Sample	Location
S1	Alappuzha District
S2	Lalitpur
S3	Vaddeswaram
S4	Pulivendula
S5	Kovilpatti
S6	Alappuzha District
S7	Ranchi
S8	Narsapur
S9	Coimbatore
S10	Chitrakoot district
S11	Trivandrum
S12	Gulbarga District
S13	Ambala Region
S14	Ludhiana
S15	Tripura
S16	Najaf City

Table 2. Classification and properties of different soil samples

S. No.	L.L (%)	P. L (%)	P. I (%)	MDD (g/cc)	OMC (%)	Classification
S1	105	38	67	1.2	29	CH
S2	83	38	45	1.10	22.5	
S3	60	31	29	1.67	18	
S4	52.1	33.5	17	1.78	16.6	
S5	48.8	43.4	5.35	1.85	13	CI
S6	47.5	27.6	19.8	1.78	14.15	
S7	43.2	31.5	11.6	1.66	24.7	
S8	41	28	13	1.51	21	
S9	40.8	20	20.8	1.8	16	CL
S10	37.3	23.1	14.1	1.87	14.5	
S11	34.9	23.4	11.5	1.54	24	
S12	32.8	21.1	11.7	2.08	9.8	
S13	32.5	20	12.5	1.86	14	Silty Sand
S14	28	15	13	1.70	16	
S15	-	-	-	2	11.08	
S16	-	-	-	1.73	9.52	

Table 3. Comparison of natural and synthetic geogrids based on key features and performance parameters

Feature	Natural Geogrids	Synthetic Geogrids
Material	Coir, jute, rubberized fibres	Polypropylene (PP), Polyester (PET), HDPE
Tensile Strength	Moderate (≈ 50 kN/m)	High (100–200+ kN/m)
Durability	Degrades over time, especially in wet soils	Long-lasting, resistant to chemical and biological decay
Moisture Sensitivity	Absorbs water; can weaken in soaked conditions	Water-resistant
Environmental Impact	Biodegradable and eco-friendly	Non-biodegradable (but durable)
Cost	Lower (locally available)	Higher (imported or processed materials)
Best Suited For	CI and CL soils in low-traffic areas	All soil types, including CH and sand

Table 4. Types of geogrids used for different types of soils

Soils		Geogrid		
Designation used for soils	Soil type	Designation used for Geogrids	Geogrid type	Tensile strength (kN/m)
S1	CH	RCG	Rubber Coir	50
S2		PG	Polyester	200
S3		BPP	Biaxial Polypropylene	100
S4		BG	Biaxial	100
S5		BPP	Biaxial Polypropylene	100
S6	CI	JG	Jute	50
S7		BPP	Biaxial Polypropylene	100
S8		PG	Polyester	200
S9		PG	Polyester	200
S10		BG	Biaxial	100
S11	CL	CG	Coir	50
S12		BPG	Biaxial polyester	200
S13		PG	Polyester	200
S14		BPP	Biaxial Polypropylene	100
S15	Silty Sand	BG	Biaxial	100
S16	Sand	HDPE	High-Density Polyethylene	200

geogrids. For CI soils with better shear strength, synthetic and natural geogrids were used because the soil isn't too weak, and natural geogrids were used to make eco-friendly options viable. For CL soils with higher CBR, low-strength geogrids were used. Natural geogrids, such as coir geogrids, were used to support eco-friendly experimental approaches. For sandy soils whose plasticity is low & CBR is high, geogrids are required to maintain the structure and load-carrying capacity properly. Geogrids like HDPE and Biaxial were used because of their excellent performance in sandy soils.

Geogrid Placement Strategy

In the design of the pavement to evaluate the subgrade soil load-carrying capacity, one of the most important tests to be performed is the California Bearing Ratio Test (CBR). The soil samples were collected and brought to the laboratory for testing. The soil of weight 5 kgs passed through a 4.75mm sieve,

blended with the optimum water content that is obtained from the Standard Proctor test, and the moisture-conditioned soil was compacted to a specific density in a standard mold of a diameter of 152.4 mm and height of 177.8 mm. The soil was compacted into 5 layers; each layer was compacted to a pre-determined number of blows of 55 with the help of a 4.89kg rammer, and the compacted soil was soaked in water for 96 hours to simulate the worst-case scenarios, such as rainfall and flooding. The CBR values of soaked conditions are generally lower compared to unsoaked conditions, highlighting the enhanced performance achieved through geogrid reinforcement. The geogrids were positioned at four different depths, 0.8h, 0.6h, 0.4h, and 0.2h in the mould from bottom to top as shown in Figure 2. The CBR test was done for both unreinforced and reinforced soil samples in soaked conditions by following codal provisions [27].

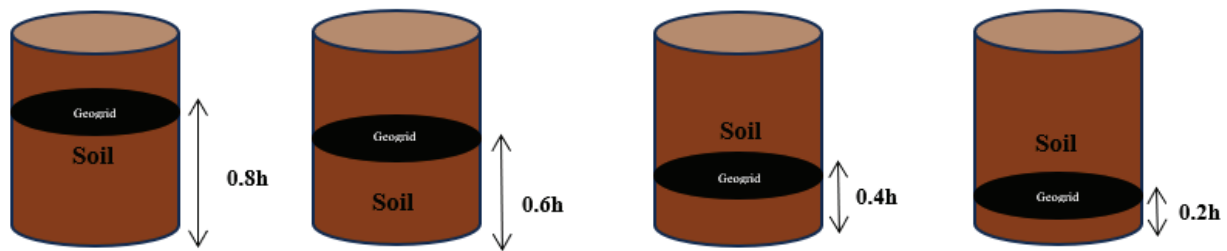


Figure 2. Placement of geogrid at various depths in the CBR mould.

The CH soil samples S1–S4 were reinforced with various welded and extruded geogrids, such as RCG, PG, BPP & BG geogrids. The soil samples S5–S10 are CI soils that were reinforced with various welded and extruded geogrids, such as BPP, PG, BPG & JG geogrids. The soil samples S11–S14 are CL soils reinforced with various welded and extruded geogrids, such as RCG, PG, BG, & BPP geogrids. The last two samples, S15 and S16, were sands that are reinforced with BG & HDPE geogrids.

RESULTS AND DISCUSSION

The results of CBR tests employing different types of geogrids positioned at varying depths on various soil samples are displayed in Table 5.

Effect of Geogrid Reinforcement at Various Depths on CBR%

The results of CBR tests performed on the 16 soil samples reinforced with various geogrids are shown in Figure 3.

To understand the influence of geogrid reinforcement on CBR% for various soil samples when they are reinforced at various depths (0.2h, 0.4h, 0.6h, 0.8h) is shown in Figure 3. From the graph, it is observed that the highest increase in CBR% was observed in sandy soil reinforced with HDPE geogrid placed in the S16 soil sample, which was observed to increase from 4.12% at 0.2 h depth to 12.8% at 0.8 h depth. The reason is that sandy soils do not retain water like cohesive soils; hence, they don't undergo swelling, shrinkage, and volume changes. Additionally, sandy soils allow better compaction, which leads to higher maximum

Table 5. CBR% for the soil samples

Types of soils	S. No	CBR %				
		Unreinforced case	Reinforced case			
			(Depth of reinforcement from Bottom of CBR mould)			
			0.2h	0.4h	0.6h	0.8h
CH	S1-RCG	3.02	3.94 (30.4%)	4.46 (47.6%)	5.28 (74.8%)	5.73 (89.7%)
	S2-PG	0.89	1.01 (13.4%)	1.26 (41.5%)	2.27 (155.0%)	-
	S3-BPP	2.8	3.0 (7.1%)	5.7 (103.5)	6.9 (146.4%)	8.7 (210.7%)
	S4-BG	1.69	1.8 (6.5%)	2.5 (47.9%)	3.91 (131.3%)	-
CI	S5-BPP	1.38	3.93 (184.7%)	4.68 (239.1%)	4.35 (215.2%)	-
	S6-JG	3.13	4.02 (28.4%)	5.36 (71.2%)	6.7 (114%)	7.15 (128.4%)
	S7-BPP	2.5	2.7 (8%)	3.2 (28%)	5.6 (124%)	9.2 (268%)
	S8-PG	2.90	5.15 (77.5%)	5.37 (85.1%)	5.62 (93.7%)	5.96 (105.5%)
	S9-PG	1.2	1.6 (33.3%)	2.67 (116.6%)	4.17 (247.5%)	-
	S10-BG	3.83	3.31 (-13.5%)	4.01 (4.6%)	4.18 (9.13%)	5.23 (36.5%)
CL	S11-CG	3.25	1.59 (-51%)	3.99 (22.7%)	6.39 (96.6%)	-
	S12-BPG	6.8	7 (2.9%)	7.2 (5.8%)	10.2 (50%)	9.5 (39.7%)
	S13-PG	3.12	-	3.28 (5.1%)	6.14 (96.7%)	8.17 (161.8%)
	S14-BPP	2.9	3.16 (8.96%)	5.8 (96.5%)	7.2 (148.2%)	9.4 (224.1%)
Silty Sand	S15-BG	4.65	7.73 (66.2%)	8.02 (72.4%)	8.5 (82.7%)	10.2 (119.3%)
Sand	S16-HDPE	2.14	4.12 (92.52%)	6.57 (207%)	9.06 (323.3%)	12.8 (498.1%)

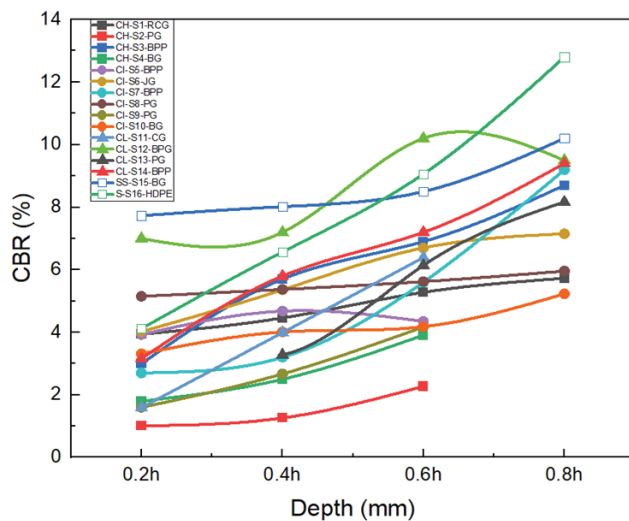


Figure 3. CBR vs. placement of geogrids at various depths.

dry densities and lower porosity. These compacted particles provide greater inter-particle friction and shear strength, both of which are critical in resisting penetration under CBR loading. When reinforced with geogrid like HDPE, the strong interlocking between sand particles and geogrid apertures further enhances the ability of soil to resist deformation. In CH soils, when the soil sample S3 was reinforced with BPP geogrid, there was a significant improvement in CBR% from 3% at 0.2 h depth to 8.7% at 0.8 h depth.

Using a similar type of geogrid at the same height for one of the CI soils, S7, the CBR% improved from 2.7% at 0.2 h depth to 9.2% at 0.8h. In the case of CL soils reinforced with BPG geogrid for the S12 soil sample, there was the highest increase in CBR% from 7% at 0.2 h depth to 10.2% at 0.6 h depth.

The optimum depth of the geogrid was determined from the literature study. The top layer placement at 0.8h exhibits higher CBR, which is consistent with the findings reported in the reference literature [19]. Even though CBR at 0.8h is higher, separate trials are done at 0.2h, 0.4h, and 0.6h because they simulate real-world scenarios, which helps the engineers to identify the best reinforcement strategy. This helps to optimize the design of reinforcement in a given pavement, ensuring active load transfer, compact deformation, and enhanced durability. The improved CBR results allow for the reduction in the thickness of the pavement by 30-50%, depending on the traffic loads and design standards. This leads to a reduction in the cost of construction. The CBR test results for the sixteen soil samples, each reinforced with different types of geogrids, are summarized in the bar graph in Figure 4.

Figure 4 reveals a general trend of increasing CBR with penetration depth for most geogrids, indicating enhanced load-bearing capacity and improved CBR% under greater deformation; this is supported by the prior studies [2, 18]. From the figures, it was clear that the highest CBR of 12.8% was achieved for S16-HDPE at a depth of 0.8h, a CBR of 10.2% for S15-BG, and a CBR value of 10.2% for S12-BPG, clearly mentioning much reinforcement capabilities. These

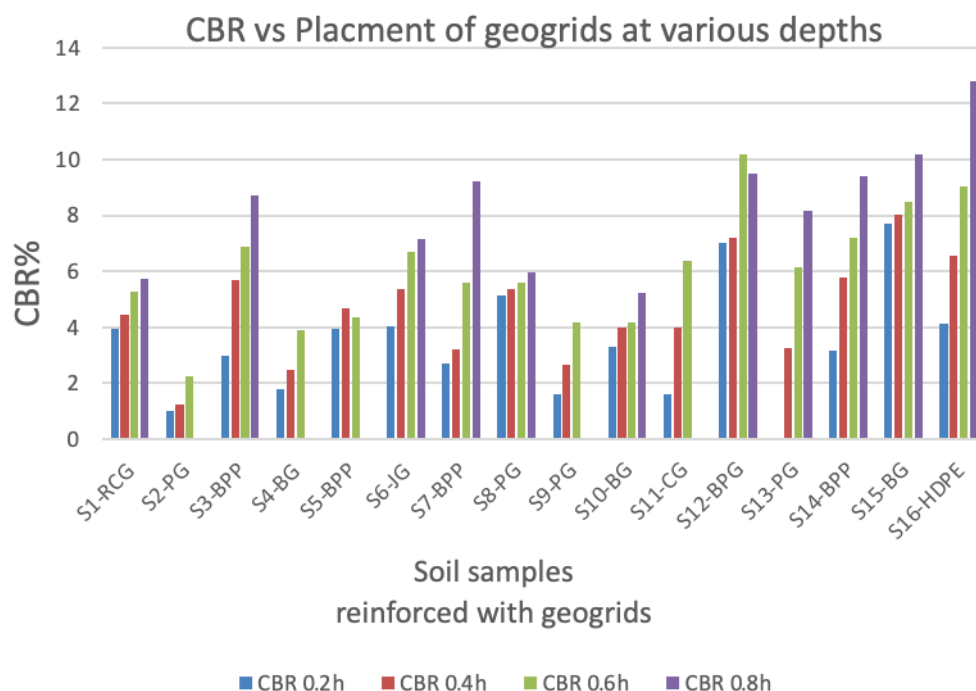


Figure 4. Comparison of the improvement of CBR for soil types reinforced with geogrids.

geogrids are mainly composed of HDPE and BG configurations, and they have high tensile strength and active stress distribution, making them suitable for stabilizing weak subgrades. This result agrees with the findings reported in the previous research as cited [17]. In contrast, S2-PG and S9-PG recorded the lowest CBR values of 1.01% and 1.6% at 0.2 h, respectively, with limited improvement at higher depths (e.g., S2-PG at 2.27% for 0.6 h).

Effect of OMC and MDD on CBR%

The California bearing ratio of soil depends upon both OMC and MDD. These two important factors determine

the strength and compaction of the soil, and they have a direct impact on CBR value. The influence of OMC and MDD on unreinforced and reinforced soil samples is shown in Figure 5-9.

The variation of CBR of soil samples with respect to OMC & MDD in unreinforced and reinforced cases is provided in Figures 4-8. For CL soils with an OMC range of 9.8% to 24% and MDD between 1.54 g/cc and 2.08 g/cc, the CBR% varied from 2.9% to 10.2%. For CI, OMC ranged from 13% to 24.7% and MDD from 1.51 g/cc to 1.87 g/cc,

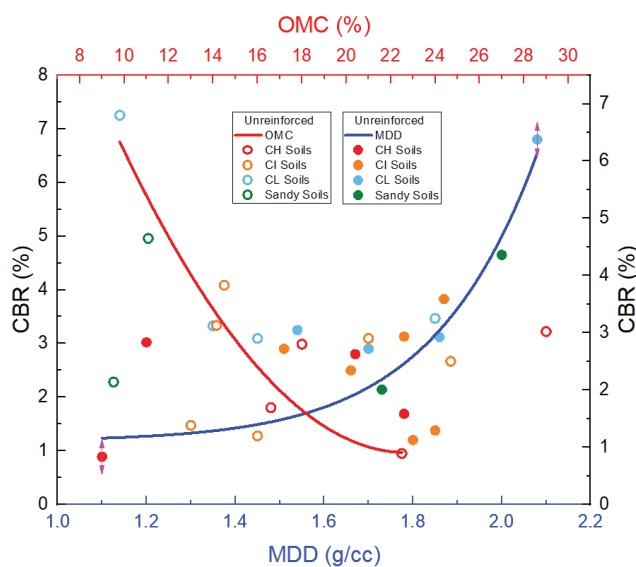


Figure 5. CBR% vs. OMC and MDD for unreinforced case.

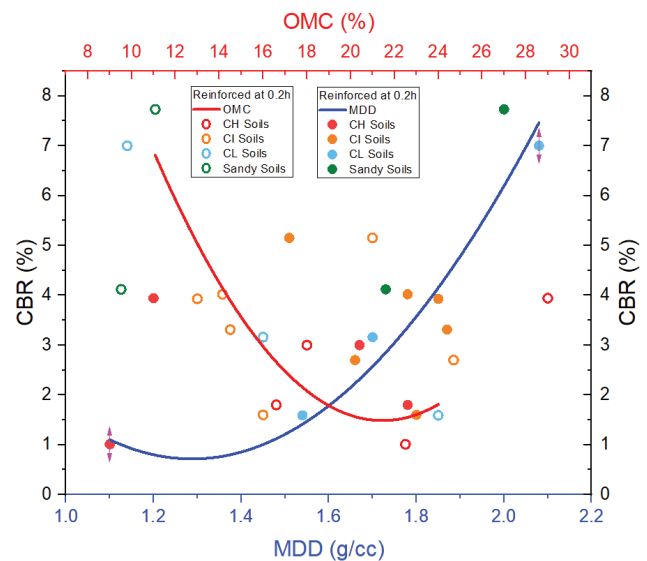


Figure 6. CBR% vs. MDD and OMC for reinforced at 0.2h depth.

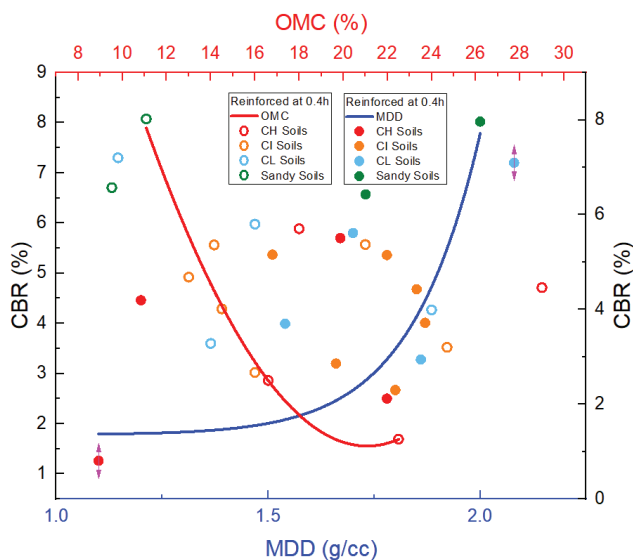


Figure 7. CBR% vs. MDD and OMC for reinforced at 0.4h depth.

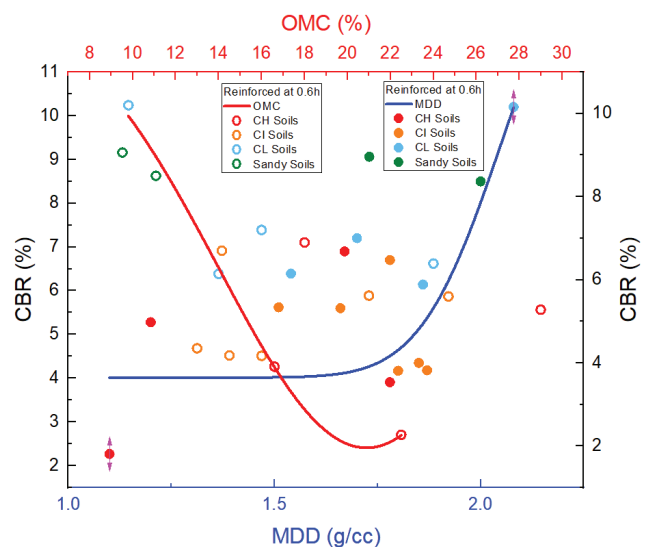


Figure 8. CBR% vs. MDD and OMC for reinforced at 0.6h depth.

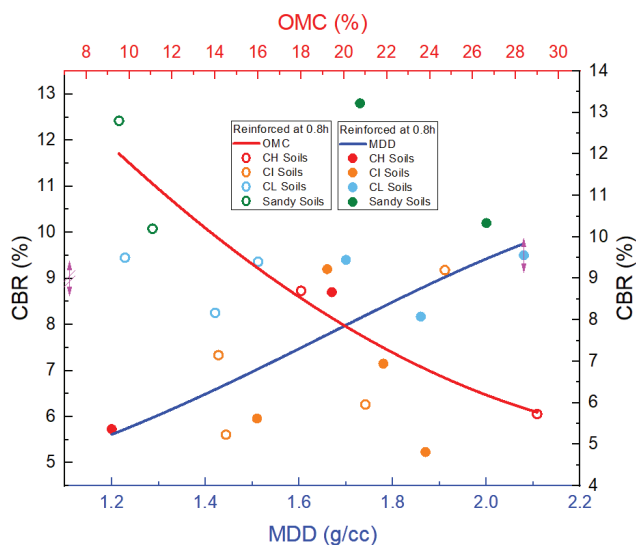


Figure 9. CBR% vs. MDD and OMC for reinforced at 0.8h depth.

with CBR% ranging from 1.2% to 9.2%. CH soils' OMC varied from 16.6% to 29%, whereas MDD ranged from 1.1 g/cc to 1.78 g/cc, with CBR values ranging from 0.89% to 8.7%. Sandy soils' OMC varied between 9.52% and 11.08%, whereas MDD varied between 1.73 g/cc has showed CBR variation from 2.14% to 12.8%.

From the results, it is clear that soil with higher MDD achieves a high CBR value, while increasing OMC has shown a decrease in CBR value, which relates to the previous literature proofs [18]. The reason behind this is that, when the water content is less than the OMC, the soil will be dry and compaction cannot be done effectively. This leads to an increase in voids and a reduction in the shear strength of the soil, thereby leading to a reduction in CBR value. Alternatively, adding water content more than the OMC also leads to a decrease in the shear strength of the soil because excess water fills the voids and causes a decrease in the friction between the soil particles, thereby resulting in a decrease in the CBR value.

The scenario at the OMC is that the soil has enough voids filled with water, making the whole mass of soil densely packed so that the soil can be compacted effectively and achieves maximum dry density, thereby achieving the highest shear strength, highest CBR, as well as load-bearing capacity. So, maintaining optimum moisture content during compaction of soil is an important parameter to be maintained to achieve dense and strong subgrade soil that is suitable for road construction as well as for foundation works.

In the case of MDD, it is evident that CBR will increase with an increase in MDD value. Generally, as the MDD of a soil increases, the CBR value also tends to increase. The reason behind achieving a higher MDD is that the soil is densely packed, leading to greater resistance to penetration

of the plunger under a given load. Alternatively, when the MDD is less means that the soil is less compacted so that less cohesion between the soil particles, leading to a decrease in CBR value, thereby reducing the load-carrying capacity of the soil. The CBR value is used in pavement design to determine the strength of the subgrade and to calculate the thickness of the pavement layers. A higher CBR, often associated with higher MDD, means that less pavement thickness may be required.

Effect of LL on CBR%

The liquid limit of a soil can affect the CBR, especially for clayey soils. Liquid limit is the moisture level at which the soil transitions from plastic to liquid form, and it is a crucial determinant of the flexibility and behaviour of soil in various moisture conditions. The influence of liquid limit on CBR is illustrated in Figure 10-14.

The relationship between the LL and CBR for various soil types (CL, CI, CH) at different reinforcement depths is illustrated in Figures 9 to 13. For unreinforced soils, as LL increases, the CBR value tends to decrease. CH soils with an LL greater than 50% achieved a lower CBR value of 3.02%, while CL soils with an LL less than 35% showed the highest value of CBR of 6.8%, and CI soils with CBR values ranging between 35% and 50% exhibited a CBR value of 3.83%. At 0.2 h depth, CL soils displayed a maximum CBR of 7%, while CH soils had shown less value of CBR of 1.01%, and the CI soils showed a CBR value of 5.15%. With variation in geogrid placement at various depths, the CBR value also varied for different soil types. At a depth of 0.4h, the CBR value of CL soil was 7.2%, while the CBR values of CH and CI soils were 1.26% and 5.37%, respectively. At the 0.6h depth, CBR values increased to 10.2% for CL soil, 2.27% for CH soil, and 6.7% for CI soil. The changes that were observed at 0.8h, is that the CBR values were 9.5%, 8.7%, and 9.2% for CL, CH, and CI soils, respectively. Among the

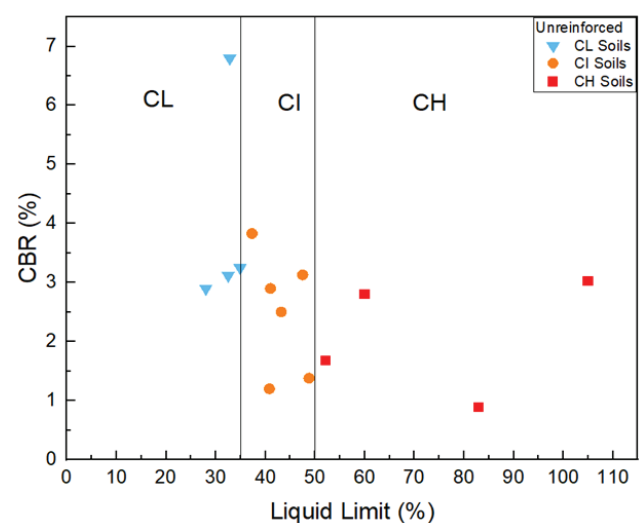


Figure 10. CBR vs. liquid limit for unreinforced case.

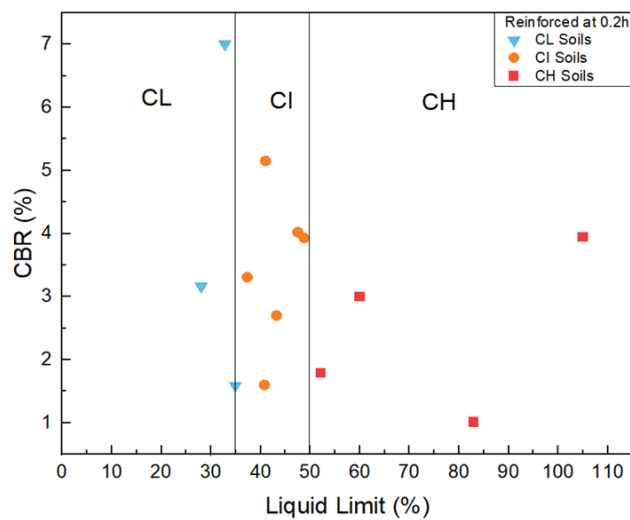


Figure 11. CBR vs. liquid limit for reinforcement at 0.2h depth.

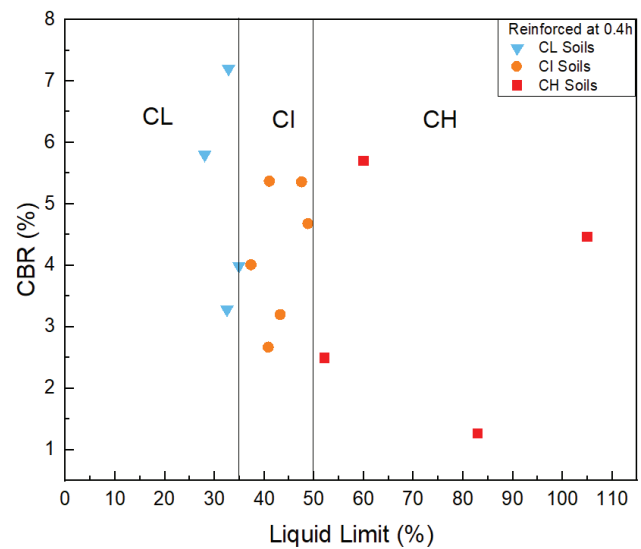


Figure 12. CBR vs. liquid limit for reinforcement at 0.4h depth.

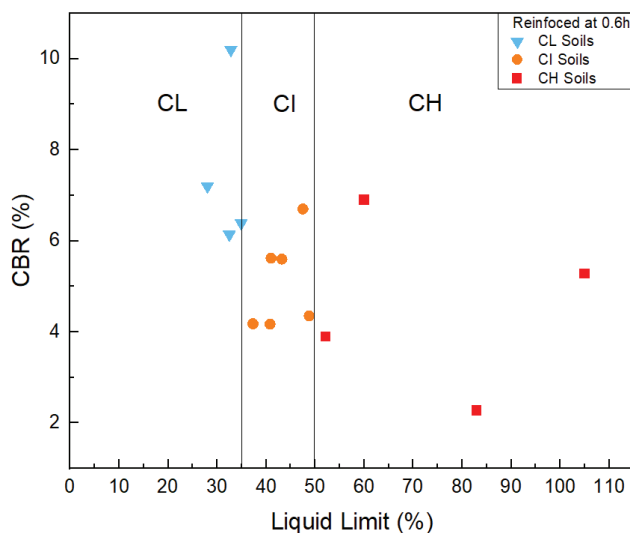


Figure 13. CBR vs. liquid limit for reinforcement at 0.6h depth.

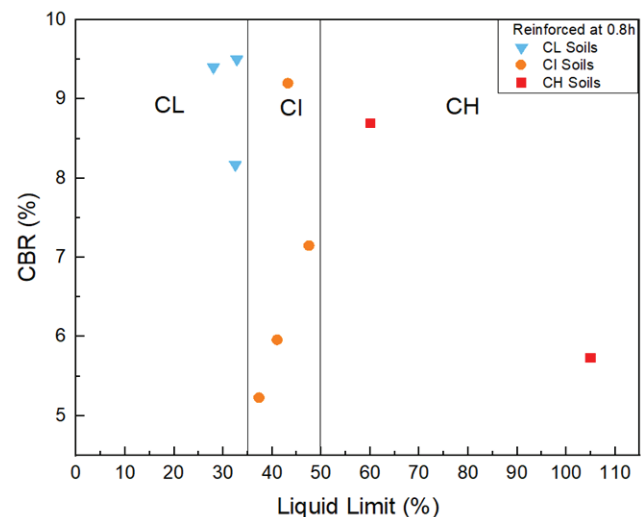


Figure 14. CBR vs. liquid limit for reinforcement at 0.8h depth.

various depths, 0.8h depth has shown notable improvement in the CBR values

In the case of clayey soils, LL is an important property that determines the CBR. From the observations, it was clear that soils with LL less than 35% have shown higher CBR values, whereas soils with LL greater than 50% has showed lesser CBR values. The reason behind this is that soils with a high LL undergoes excessive swelling, shrinkage, and deformation under the application of load, which reduces the CBR value. Also, soils with high LL generally contain a higher percentage of fine, plastic particles that tend to have lower resistance to penetration under loading,

leading to a decrease in CBR values. Soils with a lower percentage of fine particles, such as sandy and gravelly soils, show greater strength, load-carrying capacity, and higher CBR values.

This differentiation is very much helpful in the construction of pavements in which subgrade soils containing plastic and fine particles require additional measures in order to achieve high strength and support traffic loads. Depending on the conditions, the measures that can be taken include mechanical or chemical stabilization, geogrid reinforcement, or an increase in pavement layer thickness. Sandy and silty soils generally require less stabilization

when their measured CBR is sufficiently high, which can allow thinner pavement layers to be considered. The relationship between soil plasticity and CBR is also consistent with the supporting studies reported in the literature [1].

CONCLUSION

The analysis of the CBR test results on soil samples reinforced with various types of geogrids at different depths led to the following conclusions:

1. The CBR of subgrade soil has been increased significantly by the geogrid reinforcement, with a degree of improvement depending upon soil type, geogrid type, and geogrid placement depth.
2. The optimum depth of geogrid placement was 0.8h, where higher CBR values were noted for all soil types.
3. Polyester (PG), Biaxial Polypropylene (BPP), and HDPE proved greater performance in improving CBR values for CH and CI soils. This conclusion helps highway engineers in the proper selection of appropriate geogrid material for a particular type of soil.
4. Natural geogrids, such as jute (JG) and coir (CG), worked out well in case of CI and CL soils. These natural geogrids are not effective in the case of CH soils. These geogrids are suitable in areas where economical and environmentally friendly materials are preferred.
5. CL soils with $LL < 35\%$ have shown higher CBR values and after reinforcing these soils, there was even a 9% increase in their CBR values.
6. Soils with high MDD have shown higher CBR values, whereas high OMC showed a reduction in the CBR values.
7. The highest CBR of 12.8% was obtained for sandy soil reinforced with HDPE geogrid. This was mainly associated with the good compaction of sandy soil, its low plasticity, and the effective interaction between the soil and geogrid.

Future Scope

Future work should include field tests to check the results obtained from the laboratory tests under actual traffic and site conditions. Such tests would also help in studying the performance of the reinforcement over a longer period. FEM can be used to study the behaviour of reinforced soil on a larger scale and for conditions that are difficult to reproduce in the laboratory. It would also be useful to study combinations of geogrids with geotextiles or chemical stabilizers for improving weak and expansive soils. Investigating the degradation of natural geogrids over time will help optimize their use in sustainable infrastructure design.

ABBREVIATIONS

HDPE	High-Density Polyethylene
PG	Polyester Geogrid
BPP	Biaxial Polypropylene geogrid
BG	Biaxial Geogrid

BPG	Biaxial Polyester Geogrid
RCG	Rubber Coir Geogrid
JG	Jute Geogrid
CG	Coir Geogrid
CH	Highly Compressible Clay
CI	Intermediate Compressible Clay
CL	Low Compressible Clay
S	Soil Sample
OMC	Optimum Moisture Content
MDD	Maximum Dry Density
LL	Liquid Limit
PL	Plastic Limit
PI	Plasticity Index
CBR	California Bearing Ratio

AUTHORSHIP CONTRIBUTIONS

Kadali Srinivas and Ramya Krishna: Conceptualised and designed the study. Bharath Chandra: Carried out the experimental work and collected the data. All authors: Performed the data analysis & visualisation. Bharath Chandra: Drafted the manuscript. Ramya Krishna and Kadali Srinivas: Reviewed and edited the manuscript. All authors have read and approved the final manuscript.

DATA AVAILABILITY STATEMENT

The authors confirm that the data that supports the findings of this study are available within the article. Raw data that support the finding of this study are available from the corresponding author, upon reasonable request.

CONFLICT OF INTEREST

The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

ETHICS

There are no ethical issues with the publication of this manuscript.

STATEMENT ON THE USE OF ARTIFICIAL INTELLIGENCE

Artificial intelligence was not used in the preparation of the article.

REFERENCES

- [1] Vennamaneni S, Raju Aketi N, Paisa S. Reduction in pavement thickness by using geogrid. *Int J Eng Technol* 2018;7:17. [\[CrossRef\]](#)
- [2] Yadav PMG, Bharath S, Kumar MM, Reddy MN, Reddy GC. Usage of geogrid in flexible pavement design. *Int J Eng Sci Res Technol* 2018;7:144–153.

- [3] Nasser M, Tarawneh K. Development of pavement maintenance management system for an urban areas based upon multiple linear regression analysis. *Sigma J Eng Nat Sci* 2025;43:121–132. [\[CrossRef\]](#)
- [4] Singh M, Trivedi A, Shukla SK. Unpaved test sections reinforced with geotextile and geogrid. *Mater Today Proc* 2020;32:706–711. [\[CrossRef\]](#)
- [5] Suresh A, Jose D, Maliyakal GJ. CBR characteristics of soils stabilised with geogrid. *Int J Civ Eng* 2018;5:30–34. [\[CrossRef\]](#)
- [6] Pandey A, Rabbani A. Stabilisation of pavement subgrade soil using lime and cement. *Int J Eng Technol* 2017;4:5733–5735.
- [7] Abdelbaset AM, Katunský D, Zeleňáková M, El-Feky MH. Mechanical properties stabilization of low plasticity kaolin soil using fly ash and hydrated lime. *Case Stud Constr Mater* 2024;21:e03662. [\[CrossRef\]](#)
- [8] Gautam L, Maaze MR, Sharma KV. Optimizing self-compacting concrete with bone China ceramic and granite waste for improved mechanical and durability properties. *J Mater Civ Eng* 2025;37:04024525. [\[CrossRef\]](#)
- [9] Kola V, Gondu VR, Varudu RM. Mechanical and micro-structural aspects of admixture stabilized rock sludge dust. *Constr Build Mater* 2024;420:135552. [\[CrossRef\]](#)
- [10] Gautam L, Kalla P, Jain JK, Choudhary R, Jain A. Robustness of self-compacting concrete incorporating bone China ceramic waste powder along with granite cutting waste for sustainable development. *J Clean Prod* 2022;367:132969. [\[CrossRef\]](#)
- [11] Boobalan SC, Anandakumar PK, Sathasivam M. Utilization of waste plastic sheets as soil stabilization materials. *Mater Today Proc* 2023. [\[CrossRef\]](#)
- [12] Gautam L, Jain JK, Jain A, Kalla P. Recycling of bone China ceramic waste as cement replacement to produce sustainable self-compacting concrete. *Structures* 2022;37:364–378. [\[CrossRef\]](#)
- [13] Wang Z, Zhan L, Zhang H, Zheng L, Kang T. Compaction, strength, and volume change characteristics of excavated clayey soil stabilized with composite admixture of cement and autoclaved aerated concrete powder. *Can Geotech J* 2024;61:2022–2035. [\[CrossRef\]](#)
- [14] Gautam L, Jain JK, Jain A, Kalla P. Valorisation of bone-China ceramic powder waste along with granite waste in self-compacting concrete. *Constr Build Mater* 2022;315:125730. [\[CrossRef\]](#)
- [15] Janakiraman GG, Paramaguru P, Pratheep T. Stabilization of subgrade using geosynthetics. *J Adv Res Dyn Control Syst* 2019;12:169–180.
- [16] Keerthi N, Kori S. Study on improvement of sub grade soil using soil-reinforcement technique. *Int J Appl Eng Res* 2018;13:126–134.
- [17] Majedi P, Çelik S, Akbulut S. A research on the effect of the reinforcement geometry on the soil bearing capacity under the strip footing loads. *Sigma J Eng Nat Sci* 2018;36:951–960.
- [18] Mittal A, Shukla S. Strength improvement of poor subgrade soil reinforced with polyester biaxial geogrid. *Jordan J Civ Eng* 2019;13.
- [19] Lamichhane R, Acharya IP. Improvement on CBR strength of soil modified with brick dust using geogrid reinforcement. 2022.
- [20] Jayakumar J, Venkatesh J, Selvaraju YR. Expansive subgrade strength improvement using geogrid and geotextile layers. *IOP Conf Ser Mater Sci Eng* 2020;955:012064. [\[CrossRef\]](#)
- [21] Tiwari N, Satyam N. An experimental study on strength improvement of expansive subgrades by polypropylene fibers and geogrid reinforcement. *Sci Rep* 2022;12:6685. [\[CrossRef\]](#)
- [22] Zimar Z, Robert D, Zhou A, Giustozzi F, Setunge S, Kodikara J. Application of coal fly ash in pavement subgrade stabilisation: a review. *J Environ Manage* 2022;312:114926. [\[CrossRef\]](#)
- [23] Ghani ANA, Roslan NI, Hamid AHA. Road submergence during flooding and its effect on subgrade strength. *Int J GEOMATE* 2016;10:1848–1853.
- [24] Nangia T, Sharma U, Kumar S, Sharma S. Improvement of subgrade strength with the use of geotextiles-a case study. In: *International Conference on Environmental Geotechnology, Recycled Waste Materials and Sustainable Engineering*; 2023 Oct. Singapore: Springer Nature Singapore; 2023. p. 131–149. [\[CrossRef\]](#)
- [25] Nair KS, Deepthy BL. Improvement of soft subgrade using geogrid reinforcement. *Int J Eng Res Technol* 2017;5:62–64.
- [26] Balamaheswari M, Anitha B, Kanimozhi B, Naganatha Prabhu L. Improvement of California bearing ratio value in weak subgrade soil with the developed anchored geogrid. *Mater Today Proc* 2022;49:1537–1542. [\[CrossRef\]](#)
- [27] Bureau of Indian Standards. IS 2720 (Part 16): Methods of test for soils-laboratory determination of CBR. New Delhi: Bureau of Indian Standards; 1987.