Geogrid Technology: Boosting Subgrade Strength for Sustainable Infrastructure

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Abstract- Soil stabilization mean alteration of the soil properties to meet the specified engineering requirements. The use of geogrids to improve the performance of flexible pavements has increased significantly over the last decade. Geogrid have been to reinforce and strengthen paved and unpaved roads constructed on soft subgrade. They may enhance the performance and design life of flexible pavement systems. In general, geogrids reinforce subgrade soil and subbase/base layers. The experiments included an investigation of the effectiveness of a reinforcing geogrid between the sub base and the subgrade. Sections with and without reinforcement were investigated simultaneously by a two-dimensional geogrid placing 2 layers, 3 layers in between the subgrade. The test results were compared with existing designs for flexible pavement layers and the performance of the reinforcement was examined over a wide range of test conditions from soft to stiff. The experimental concentration on measuring the effect of subgrade strength, sub base thickness and effectiveness of a reinforcing geogrid. The results are assessed in terms of flexible pavement layer and the effects of difference between the test conditions with using geogrid and without using geogrid are discussed.
Key words: Soil Stabilization, Geogrids, Flexible Pavements, Subgrade Strength

1. INTRODUCTION

In India, large areas are covered by black cotton soils, which exhibit swelling and strength loss upon water absorption, posing significant challenges for road construction. Roads built on such subgrades often suffer from excessive deformation, undulations, and reduced service life. Addressing these issues typically requires thicker pavement layers, significantly increasing construction costs. Geogrids, known for their tensile strength and reinforcement properties, provide a cost-effective solution by improving the engineering characteristics of pavement systems. Laboratory investigations highlight the effectiveness of geogrids in stabilizing weak soils, reducing pavement thickness, and enhancing durability, making them a vital tool in sustainable road construction.

Objectives of the Project:

1. To enhance the strength and stability of weak soils using geogrid materials.
2. To optimize pavement design by incorporating geogrid reinforcement.
3. To evaluate the effectiveness of geogrids in reducing pavement thickness.
4. To estimate the cost and performance of pavement construction with geogrid integration.

2. LITERATURE REVIEW

1. "Use Of Geo-Grids in Flexible Pavement Design" (2023)by M. S. Jagadish, D. S. Kumaraswamy, and V. T. Santosh – This research examines the application of geogrids to improve the engineering properties of pavement systems. It highlights significant improvements in CBR values and reductions in pavement layer thickness, enhancing both performance and cost efficiency.
2. "Design of Flexible Pavements by Using Geo-Grids" (2022) by Dr. M. Kumar, P. Gupta, and S. Rajesh – The paper focuses on the integration of geogrids into flexible pavement designs, addressing weak soils. It discusses methods to optimize pavement construction costs while maintaining structural integrity and durability.
3. "Improvement of Flexible Pavement With Use of Geogrid"(2022) by K. Prabhakar, G. Saravanan, and A. Kumaravel – This study presents laboratory tests on weak soils like black cotton soil, showcasing how geogrids significantly improve soil strength, reduce deformation, and extend pavement life, making them ideal for challenging subgrades.
4. "Reducing Highway Construction Costs by the Use of Geo-Grids in Flexible Pavement"(2015) by Dr. M. R. Deshmukh and V. B. Reddy – The paper discusses the economic advantages of using geogrids, particularly in reducing pavement thickness. It also highlights the long-term cost benefits through enhanced pavement durability and reduced maintenance needs.

3. EXPERIMANTAL INVESTIGATION

The experiments conducted include Sieve Analysis for soil classification, Atterberg Limits to measure soil consistency, Specific Gravity Test for density, Standard Proctor Test for compaction properties, and California Bearing Ratio (CBR) Test to assess subgrade strength. These tests help classify soil, predict its behaviour, and design effective pavements, especially when using soil reinforcement methods like geogrids.

4. RESULTS AND DISCUSSIONS

a. Grain size analysis for first sample

Table4.1: Grain size analysis for first sample

IS sieve no	Particle Size	Weight retained	% weight retained	Cumulative % retained	Cumulative % finer(100-x)
4.75mm	4.75	105	10.5	10.5	89.5
2.36mm	2.36	75	7.5	18	82
1.18mm	1.18	285	28.5	46.5	53.5
600	600	175	17.5	64	36
425	425	100	10	74	26
300	300	120	12	86	14
150	150	90	9	95	5
75	75	25	2.5	97.5	2.5

Based on the sieve analysis data, the soil sample shows a distribution of particles across various sieve sizes, with a significant proportion of finer particles. The cumulative percentage finer at each sieve size indicates that the sample predominantly consists of fine and medium-grained particles. The highest percentage retained was 28.5% on the 1.18mm sieve, followed by a significant decrease in particle size as we moved towards finer sieves. The cumulative percentage finer shows a steady increase as the sieve size decreases, suggesting that the soil is more fine-grained. The soil has a higher percentage of fine particles, with only 2.5% passing through the 75-micron sieve, indicating that it is likely to be classified as silt or clay according to the Unified Soil Classification System (USCS). The soil is not well-graded, as indicated by the lack of a broad range of particle sizes. This analysis suggests the soil may have poor drainage characteristics and could require stabilization or reinforcement for use in construction projects.

b. Liquid limit and Plastic limit:

Table4.2: Liquid limit and Plastic limit for first sample

Observations	**trail**
Cup number	63
Weight of cup (W_1)	15gm
Weight of cup +wet soil (W_2)	40gm
Weight of cup +oven dried soil (W_3)	36gm
Weight of water (W_W=W_2-W_3)	4gm
Weight of oven dried soil (W_S = W_3-W_1)	21gm
Water content w= W_W/ W_SX100	19.04%

Based on the observed data for the Liquid Limit and Plastic Limit tests:

- **Liquid Limit**: The water content of the soil at the liquid limit is calculated to be **19.04%**. This indicates that the soil is in a liquid state when the moisture content is higher than this value, and as the moisture content decreases, the soil transitions to a plastic state. The liquid limit helps classify fine-grained soils and indicates the soil's ability to deform under stress.
- **Plastic Limit**: The water content at the plastic limit is found to be **16.66%**. This marks the boundary between the plastic and semi-solid states of the soil. The plastic limit represents the moisture content at which the soil can no longer be molded without cracking.

The difference between the liquid limit and plastic limit (**Plasticity Index = 19.04% - 16.66% = 2.38%**) suggests that the soil is of low plasticity.

c. Specific gravity

Table4.3: specific gravity of the soil

Parameters	**Trail1**
Weight of pycnometer (W1)	0.607kg
Weight of pycnometer +oven dried soi (W2)	0.875kg
Weight of pycnometer +soil +water(W3)	1.625kg
Weight of pycnometer +full of water (W4)	1.464kg
Weight of soil (W2-W1)	0.268kg
Weight of water filling pycnometer (W4-W1)	0.857kg
Weight of water above soil (W3-W2)	0.750kg
Average specific gravity	2.49

The specific gravity of the soil is calculated to be 2.49. This value indicates that the soil particles are denser than water, as typical specific gravity values for soil range between 2.5 and 3.0.

d. Standard Proctor Test

The results of the compaction test indicate the following:

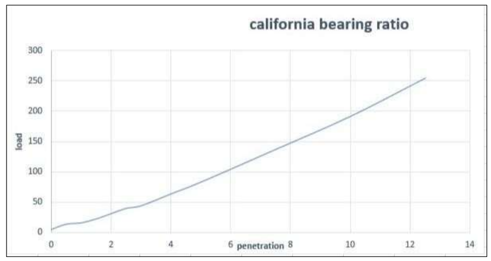
s.no	Weight of mould +compacted soil	Weight of compacted soil (kg)	r=w/v	Water content (%)	rd=r/1+w
1	4053	2054	2.126	11.11	1.913
2	4139	2140	2.215	11.16	1.992
3	4138	2139	2.214	14.28	1.937

1. The maximum dry density (MDD) is observed at 1.992 g/cm³, corresponding to a water content of 11.16%.
2. The dry density values decrease slightly when the water content increases to 14.28%, suggesting that the soil has reached its optimum moisture content (OMC) near 11.16%.

This behaviour aligns with the standard compaction curve, where soil achieves maximum density at its OMC. The data suggests that for effective compaction in field conditions, the water content should be maintained close to 11.16% for the best results in achieving maximum soil density. This is crucial for enhancing the strength and stability of soil layers in construction applications.

e. California bearing ratio test

Readings	penetration	Proving ring readings	Load (kg)
0	0	4	4.36
50	0.5	12	13.08
100	1	14	15.26
150	1.5	20	21.8
200	2	28	30.52
250	2.5	36	38.24
300	3	40	43.6
400	4	58	63.22
500	5	76	82.84
750	7.5	126	137
1000	10.0	176	191.84
1250	12.5	234	255.06



The California Bearing Ratio (CBR) test results indicate the following: The CBR test results indicate that the soil has a CBR value of 4.03%, based on the load at 5 mm penetration being higher than at 2.5 mm. This value suggests the soil is relatively weak and may require stabilization or reinforcement to improve its strength for use in pavement construction.

f. specific gravity test for second sample:

Observations	Trail
Weight of pycnometer (w1)	0.607kg
Weight of pycnometer +oven dried soil (w2)	0.95kg
Weight of pycnometer +soil +water (w3)	1.654kg
Weight of pycnometer +full of water (w4)	1.443kg
Weight of soil w2-w1	0.353kg
Weight of water filling pycnometer	0.836kg
Average specific gravity	2.59

The results of the second trial indicate that the specific gravity of the soil is 2.59, which is within the typical range for mineral soils (2.5–3.0).

g. Standard Proctor Test

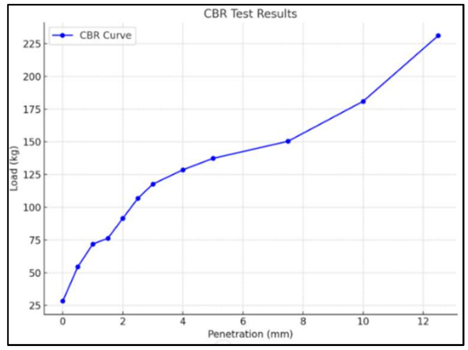
s. no	Weight of mould +compacted soil	Weight of compacted soil	r=w/v	Water content	rd =r/1+w
1	3.6	1600	1.65	10	1.45
2	3.8	1800	1.86	13	1.59
3	3.9	1900	1.96	16	1.637
4	3.96	1960	2.02	19	1.647
5	3.956	1956	2.024	22	1.603
6	3.845	1845	1.909	25	1.476

The compaction test results indicate the following:

1. The maximum dry density (MDD) is observed at 1.647 g/cm³, corresponding to a water content of 19%, which is the optimum moisture content (OMC) for this soil.
2. Beyond 19% water content, the dry density starts to decrease, indicating that excess water hinders soil compaction due to the reduced expulsion of air voids.

h. California bearing ratio test by using geogrid (2 layers)

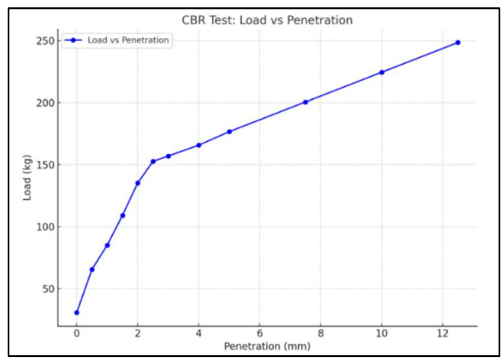
Readings	penetration	Proving ring readings	Load (kg)
0	0	26	28.34
50	0.5	50	54.5
100	1	66	71.94
150	1.5	70	76.3
200	2	84	91.56
250	2.5	98	106.82
300	3	108	117.72
400	4	118	128.62
500	5	126	137.34
750	7.5	138	150.42
1000	10.0	166	180.94
1250	12.5	212	231.08



The CBR test results show a steady increase in load with penetration, with notable points at 2.5 mm and 5 mm penetration. Based on the standard CBR values for penetration depths of 2.5 mm and 5 mm, the soil exhibits good load-bearing capacity. The load at 2.5 mm is 106.82 kg, and at 5 mm, it is 137.34 kg.

i. California bearing ratio test using Geogrid (3 layers)

Readings	penetration	Proving ring readings	Load (kg)
0	0	28	30.52
50	0.5	60	65.4
100	1	78	85.02
150	1.5	100	109
200	2	124	135.16
250	2.5	140	152.6
300	3	144	156.96
400	4	152	165.68
500	5	162	176.58
750	7.5	184	200.56
1000	10.0	206	224.54
1250	12.5	228	248.52



The data demonstrates a consistent increase in load with penetration, indicating the material's ability to resist incremental stress. Up to 5 mm, the load-penetration relationship is linear, reflecting uniform resistance. Beyond this point, a slight nonlinearity emerges, suggesting material densification under higher loads. The peak load of 248.52 kg at 12.5 mm penetration highlights the material's maximum bearing capacity, making it suitable for load-bearing applications.

5. CONCLUSIONS

Table 5.1 CBR test results

s. no	Soil properties	First sample	Second sample
1	Specific gravity	2.49	2.59
2	Grain size distribution	C_u=4.70 C_C=0.423	-
3	Atterberg's limits	L.L =19.04% P. L=16.66%	-
4	Standard proctor test	OMC=11.16%	OMC=19%
5	CBR	At 2.5mm=2.86% At 5mm=4.03%	-
6	Trail 1	-	At 2.5mm=7.79 At 5mm=6.68
7	Trail 2	-	At 2.5mm=11.13 At 5mm=8.59

- **Soil Strength**: The second sample shows significant improvements in CBR values, indicating better strength and stability, especially with the higher CBR values observed in both trials.
- **Compaction and Moisture Sensitivity**: The first sample has a lower OMC, which may make it easier to compact compared to the second sample, which requires more moisture for optimal compaction.
- **Soil Suitability**: Based on the higher CBR values and specific gravity, the second sample appears to be more suitable for engineering applications where higher load-bearing capacity is required, such as in pavements and road construction.

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