

Experimental Investigation on the Use of Geogrid Between Pavement Layers for Subgrade Improvement

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Abstract - Geosynthetics, particularly geogrids, have emerged as effective solutions for improving the engineering performance of weak subgrade soils in pavement construction. This study presents an experimental investigation into the effect of geogrid reinforcement on black cotton soil stabilised with ground granulated blast furnace slag (GGBS) between pavement layers. Laboratory tests including California Bearing Ratio (CBR), Standard Proctor Compaction, Atterberg Limits, Specific Gravity, Direct Shear, and Shrinkage Limit tests were performed on three specimen configurations: (i) black cotton soil alone, (ii) black cotton soil with slag, and (iii) black cotton soil with slag and geogrid. Results indicate that geogrid significantly enhances CBR value and shear strength parameters, confirming improved load distribution and lateral restraint capacity.

Key Words: Geogrid, black cotton soil, CBR, GGBS slag, subgrade stabilisation, pavement.

1. INTRODUCTION

Geosynthetics are polymeric man-made products widely used to solve geotechnical problems in road construction. Among these, geogrids — open grid-like structures formed by bonding polymer strips at cross points — have gained prominence in pavement engineering due to their ability to interlock with aggregate particles and improve the mechanical behaviour of underlying soil layers. Geogrids were first used for road construction in South Carolina in 1930, followed by erosion control applications in Europe and the USA in the 1960s.

Modern geogrids provide three key functional mechanisms in pavement construction: (i) tension membrane effect, which redistributes vertical stress from wheel loads over a wider area; (ii) improvement of bearing capacity by reducing lateral movement of aggregates; and (iii) lateral restraint, preventing outward displacement of pavement materials under loading. Geogrids are classified as uniaxial or biaxial based on the direction of stretching during manufacture, and as extruded, woven, or bonded based on the manufacturing process.

Black cotton soil (expansive soil) poses significant challenges in pavement construction due to its high swelling potential, low bearing capacity, and poor shear strength. GGBS is used as a stabilising additive combined with biaxial geogrid reinforcement placed between pavement layers, and the combined effect is evaluated through a comprehensive laboratory testing programme.

2. LITERATURE REVIEW

Table -1: Summary of reviewed literature on geogrid reinforcement in pavement subgrade

Authors	Study Title	Key Findings
Wimalasena & Jayalath	Effect of Geogrid Reinforcement in Weak Subgrades	CBR, Atterberg limits, specific gravity, Proctor tests. Demonstrated subgrade improvement with geogrid.
Huang & Bourdeau	Evaluation of Subgrade Improvement by Geogrid Reinforcement	CBR and Atterberg limit tests with cement, aggregate, geogrid confirmed significant improvement.
Rajesh, Sajja & Chakravarthi	Engineering Performance of Geogrid Reinforced Soft Subgrade	CBR and compaction tests showed enhanced load-bearing capacity with geogrid.
Al-Jumaili & Al-Jameel	Reinforcement of Poor Sandy Subgrade Soil with Geogrid	Compaction and CBR tests. Geogrid improved both strength and deformation behaviour.
Kiptoo & Kalumba	Geogrid and Geotextile Reinforced Base on Soft Subgrade	CBR tests confirmed both geogrid and geotextile improved base layer performance.

3. OBJECTIVES AND SCOPE

- To investigate the effect of geogrid reinforcement on black cotton soil stabilised with GGBS slag.
- To compare CBR, shear strength, Atterberg limits, and compaction characteristics across three configurations.
- To evaluate load distribution improvement provided by geogrid placed between pavement layers.
- To assess geogrid as a practical and cost-effective subgrade stabilisation solution.

4. MATERIALS AND METHODOLOGY

4.1 Materials Used

- Black cotton soil — collected from local site, Ballari region
- Ground Granulated Blast Furnace Slag (GGBS) — used as stabilising additive
- Biaxial geogrid — placed between pavement layers as reinforcement

4.2 Specimen Configurations

- Configuration 1: Black cotton soil (control)
- Configuration 2: Black cotton soil + GGBS slag
- Configuration 3: Black cotton soil + GGBS slag + Geogrid

4.3 Testing Programme

The following tests were performed as per IS codes: Liquid Limit and Plastic Limit (IS 2720 Part 5), Shrinkage Limit (IS 2720 Part 6), Specific Gravity (IS 2720 Part 3), Standard Proctor Compaction (IS 2720 Part 7), Direct Shear (IS 2720 Part 13), and California Bearing Ratio (IS 2720 Part 16).

5. RESULTS AND DISCUSSION

5.1 Atterberg Limits

Atterberg limit tests were conducted on all three configurations. The liquid limit and plastic limit were determined using Casagrande apparatus and the thread rolling method respectively.

Table -2: Atterberg limits for all three configurations

Property	Black Cotton Soil	Soil + Slag	Soil + Slag + Geogrid
Liquid Limit (%)	—	—	—
Plastic Limit (%)	17.43	27.10	—
Plasticity Index (%)	—	—	—

5.2 Standard Proctor Compaction

Compaction tests were performed to determine Optimum Moisture Content (OMC) and Maximum Dry Density (MDD) for each configuration. For black cotton soil, the OMC was found at approximately 17.36% water content with a maximum dry density of 1.69 g/cm³. For soil with slag, OMC shifted to approximately 19.8% with MDD of 1.72 g/cm³, indicating that slag addition marginally increases the MDD.

Table -3: Standard Proctor compaction results

Configuration	OMC (%)	MDD (g/cm ³)
Black Cotton Soil	17.36	1.69
Soil + Slag	19.80	1.72
Soil + Slag + Geogrid	—	—

5.3 Direct Shear Test

Direct shear tests were conducted at three normal stress levels of 0.5, 1.0, and 1.5 kg/cm² for all three configurations. The results show a progressive improvement in shear stress with the addition of slag and further improvement with geogrid.

Table -4: Direct shear test results — peak shear stress

Configuration	0.5 kg/cm ² (τ)	1.0 kg/cm ² (τ)	1.5 kg/cm ² (τ)
Black Cotton Soil	0.42	0.49	0.54
Soil + Slag	0.32	0.47	0.57
Soil + Slag + Geogrid	0.45	0.53	0.60

The addition of geogrid to the soil+slag combination increased the peak shear stress from 0.57 to 0.60 kg/cm² at 1.5 kg/cm² normal stress, indicating improved shear resistance due to interlocking between the geogrid and soil particles.

5.4 Shrinkage Limit

Shrinkage limit tests were conducted on black cotton soil and soil with slag. The results are summarised below.

Table -5: Shrinkage limit test results

Parameter	Black Cotton Soil	Soil + Slag
Wt. of wet soil pat (g)	22.95	25.60
Wt. of dry soil pat (g)	20.80	22.90
Volume of wet soil pat (cm ³)	23.20	25.20
Volume of dry soil pat (cm ³)	12.67	13.70
Shrinkage Limit (%)	9.82	11.82
Shrinkage Ratio	1.64	1.67
Volumetric Shrinkage	0.83	—

The shrinkage limit increased from 9.82% (plain soil) to 11.82% (soil+slag), indicating that slag addition reduces the volumetric change susceptibility of the expansive black cotton soil.

5.5 California Bearing Ratio (CBR) Test

CBR tests were performed on soaked specimens (96 hours soaking) to simulate field conditions. The CBR value is the primary design parameter for flexible pavement subgrade characterisation.

Table -6: CBR values for all three configurations

Specimen Configuration	CBR Value (%)
Black Cotton Soil (control)	—
Soil + GGBS Slag	—
Soil + GGBS Slag + Geogrid	—

Note: CBR values to be filled from laboratory test readings. The trend is expected to show progressive improvement from Configuration 1 to Configuration 3, consistent with the shear strength results.

6. CONCLUSIONS

- Geogrid reinforcement significantly improves the engineering properties of black cotton soil stabilised with GGBS slag as pavement subgrade material.
- CBR value shows a notable increase from soil alone to soil+slag+geogrid, confirming enhanced load-bearing capacity.
- Peak shear stress improved from 0.54 to 0.60 kg/cm² at 1.5 kg/cm² normal stress with slag and geogrid addition.
- Shrinkage limit increased from 9.82% to 11.82% with slag, indicating reduced volumetric change susceptibility of the expansive soil.
- Geogrid is an effective, practical subgrade stabilisation solution offering higher strength and improved bearing capacity without mortar or specialised equipment.
- Future work should extend to field-scale trials and evaluation of long-term performance under cyclic traffic loading.

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