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UTILIZATION OF MINE OVERBURDENED MATERIALS IN LOW VOLUME ROADS SUBBASE/BASE WITH COCONUT COIR GEOTEXTILE REINFORCEMENT

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Abstract

This research investigates the feasibility of incorporating mine-overburdened materials into low-volume road construction, particularly in subbase and base layers, through small-scale laboratory testing. Mine overburdened materials, typically considered as waste, have the potential to serve as cost-effective alternatives in road construction. However, these materials often fail to meet the stipulated criteria of the Ministry of Road Transport and Highways (MoRTH) specifications. The study focuses on enhancing the mechanical properties of the overburdened materials that are obtained to meet the standards. Laboratory experiments, including modified proctor tests and California Bearing Ratio (CBR) testing, were conducted to assess the engineering characteristics of the mine-overburdened materials. The results indicated that, in their natural state, these materials do not conform to MoRTH [1] standards. The experimental results reveal a notable improvement in the engineering properties of the mine's overburdened materials when combined with coconut coir geotextiles. The modified proctor tests demonstrate enhanced compaction characteristics, while CBR testing indicates 1.84 times improvement when compared with the unreinforced mine overburdened materials. Using coconut coir geotextile effectively improves the suitability of mine overburden materials for low-volume road construction, promoting sustainable and cost-effective practices.

Keywords: mine overburdened materials, coconut coir geotextiles, CBR test, modified proctor test

1 Introduction

Low-volume roads typically refer to roads with relatively low traffic volumes, often serving rural or less populated areas. They are characterized by lower vehicle counts and reduced speeds compared to major highways and urban roads. Low-volume roads are vital infrastructure networks that provide access to remote communities, facilitate economic activities, and support social inclusion. However, as shown in Figure 1, these roads often face challenges related to poor conditions, limited resources, and environmental concerns.

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Figure 1 Damaged Low-volume Roads

In this context, the utilization of mine-overburdened materials (MOMs) presents a promising opportunity for road construction. MOMs, which are generated as a byproduct of mining operations, often consist of soil, rock, and other materials that can be processed and utilized in various civil engineering applications. Mallick [2] has investigated the utilization of mine waste materials in road construction as a cost-effective and environmentally sustainable alternative to traditional aggregates. Mine waste, including overburdened materials, presents an abundant resource that can be repurposed for road infrastructure, thereby reducing environmental impact and conserving natural resources.

Moreover, natural geotextiles have emerged as promising reinforcement materials for enhancing the performance of road infrastructure. Numerous studies have explored the potential of natural materials like jute, coir fiber, and bottom ash in improving soil properties and reinforcing road construction materials. Thakur [3] investigated the degradation of untreated and Bitumen Emulsion Treated (BET) jute geotextiles, noting that BET jute exhibited superior durability against deterioration compared to untreated jute. Karthikeyan [4] evaluated bottom ash (BA) and coir fiber as reinforcing agents for weak clayey soil, recommending their combined use to enhance soil stabilization. Kolathayar [5, 6] explored the reinforcement of sand and clay beds with coir and sisal geocells, highlighting the superior performance of coir geocells in enhancing bearing capacity and settlement characteristics. Shukla [7] investigated the benefits of incorporating coir fiber into road construction materials, emphasizing its positive effects on soil subgrade and bituminous mix properties. Anusudha [8] conducted experimental and numerical analyses on coir geotextile-reinforced organic soil, demonstrating significant improvements in strength and stiffness. Evangeline [9] studied the use of coir geotextiles in pavement construction, reporting reduced deflection and improved CBR values in reinforced roads. Rao [10] discussed the development of coir geotextiles and their suitability for low-traffic areas based on laboratory and field research. Meshram [11] emphasized the need for collaboration to innovate and market coir products, especially in the expanding market for coir geotextiles. Sayida [12] investigated using geotextile reinforcement to improve soft subgrade on paved roads, highlighting potential cost savings and improved performance. Subaida [13] conducted laboratory tests on the reinforcing advantages of woven coir geotextiles, emphasizing the need for further research on unpaved road sections. Jaswal [14] explored the benefits of using chemically treated coir geotextiles on unpaved roads, highlighting enhanced load-bearing capacity and reduced pavement thickness as economically viable solutions.

The Indian Standards (IS) specification IRC SP:59 [15] provides guidelines for the use of geotextiles, including jute and coir technology, in road pavements and associated works. Under the Pradhan Mantri Gram Sadak Yojana (PMGSY) until March 31, 2022, a total road length of 1,061 kilometers has been constructed using Coir Geotextile across the country.However, despite the advancements in utilizing mine waste materials and natural geotextiles, limited research has been conducted on their combined application for improving low-volume roads. The novelty of our research lies in the integration of mine waste materials, particularly overburden materials, with coconut coir geotextiles to enhance the strength, durability, and sustainability of low-volume roads.

2 Materials and methodology

2.1 Selection of mine overburden materials

Mining locations are selected according to availability, accessibility, and proximity to prospective road development sites. The selection process will consider elements, including the composition of overburden materials, geological parameters, and environmental requirements. Within the designated mining areas, mine overburdened materials (MOMs) samples were collected from various locations. Sampling was carried out using standard procedures to provide representative samples that encompass the variability in material properties. The MOM samples, such as Clay, Sandstone, and Basaltic rocks, have undergone laboratory testing to ascertain their physical, chemical, and mechanical qualities. Tests, including grain size analysis, Atterberg limits, direct shear, and compaction characteristics, will be performed to evaluate the appropriateness of MOMs for road building.

Table 1 Properties of Mine Overburden soils:

Properties	Clay	Sandstone	Codal specification
Soil classification	CL	SC	ASTM D2487-11
Liquid limit [%]	76.9	46.28	IS 2720 (Part-V)
Plasticity limit [%]	48.3	41.96	IS 2720 (Part-V)
Plasticity index [%]	28.6	4.32	IS 2720 (Part-V)
Optimum moisture content [%]	21.2	16.67	IS 2720 (Part VII)
Maximum dry density [g/cc]	2.144	2.42	IS 2720 (Part VII)
CBR [%]	1.64	6.41	IS 2720 (Part XVI)
Direct shear test c [kPa] & ϕ	24.51 & 36.05°	0 & 28.51°	IS 2720 (Part XI)

Figure 2 Procurement of Mine Overburden Materials from the Open-cast Mine.

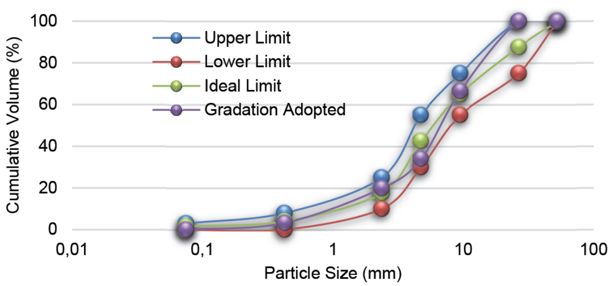

Figure 3 Showing adopted aggregate grading VI as per MoRTH (2013) for the GSB layer.

Basalt rock procured from the mine has been transported to the nearest stone crusher plant and crushed as per the required size according to the gradation adopted as per MoRTH [1], Gradation VI, Table 400-1 of clause 401.2 as shown in Figure 3. For the above aggregates' laboratory-tested properties of aggregates are tabulated in Table 2 below.

Table 2 Properties of Mine Overburden Aggregates

Properties	Basalt	Codal specification
Specific gravity	2.98	IS2386 (Part III)
Water absorption [%]	1.09	IS2386 (Part III)
Impact test [%]	5.76	IS2386 (Part IV)
Crushing test [%]	15.33	IS2386 (Part IV)
LA abrasion test [%]	20.06	IS2386 (Part IV)

2.2 Procurement and preparation of coconut coir geotextile

Coconut coir geotextiles were procured from reliable suppliers specializing in natural fiber geotextiles, as shown in Figure 4. The geotextiles will be selected based on their physical properties, including tensile strength, elongation, and tearing resistance, as shown in Table **3** below. Prior to testing, the coconut coir geotextiles will be conditioned to achieve consistent moisture content and physical properties. Conditioning procedures will be performed according to relevant standards and manufacturer guidelines.

Figure 4 Coconut coir geotextile (CGT)

Table 3 Properties of Coconut coir geotextile

Properties	Obtained value	Codal specification
Thickness [mm]	3	-
Weight [g/m^2]	850	ASTM D 5261
Apparent opening size [mm]	20	ASTM D 4751
Tensile Strength [kN/m]	13 at 12% Strain	BS 6906 (Part I)

2.3 Methodology

The research methodology commenced with the initial steps of selecting Mine Overburden Materials (MOMs) and procuring Coir Geotextile (CGT) from the mine and a reliable vendor, respectively. Subsequently, the materials underwent various laboratory tests to determine their engineering properties. The modified Proctor test was then conducted on the samples to calculate the Optimum Moisture Content (OMC) and Maximum Dry Density (MDD) for different combinations, including those with and without CGT. Following this, California Bearing

Ratio (CBR) tests were performed on the resulting combinations, and the results were subsequently analyzed.

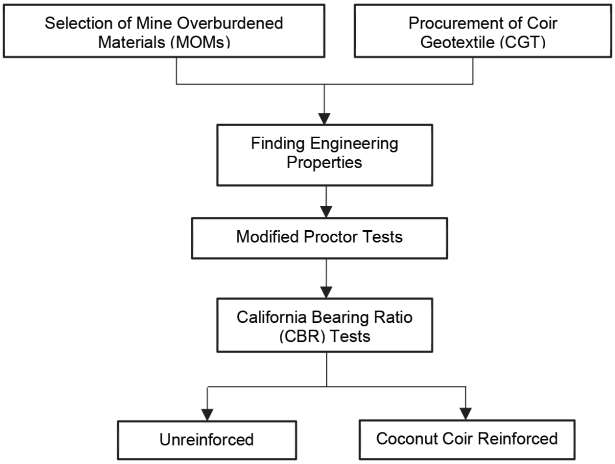

Figure 5 Methodology of the Present Study

3 Tests performed

The current study explores the utilization of overburdened materials in low-volume road construction for GSB/Baselayers. These overburdened materials, referred to as MOMs, lack the strength and capacity of virgin aggregates. To enhance the strength of this layer, reinforcement is introduced in the form of coconut coir geotextiles. Various laboratory tests, including Modified Compaction tests and California Bearing Ratio tests, have been conducted to assess both unreinforced and reinforced criteria.

3.1 Compaction tests

Compaction tests were conducted to evaluate the maximum dry density (MDD) and optimum moisture content (OMC) of the mine overburdened materials (MOMs) with and without coconut coir geotextile reinforcement. The modified Proctor compaction test (IS 2720 part-8: 1983) was performed using a standard level of compaction effort to simulate field conditions. The sample was placed in five layers and compacted. It came under heavy compaction.

Figure 6 Compaction of sample for modified proctor test

3.2 California bearing ratio (CBR) tests

California Bearing Ratio (CBR) tests were conducted to assess the load-bearing capacity and resilience of the reinforced MOMs under simulated traffic loading conditions, Fig. 7.

Figure 7 CBR test on sample

The CBR test (IS 2720, Part-16: 1987) involves subjecting cylindrical specimens of compacted MOMs to incremental loads and measuring the penetration resistance at each load increment. The sample is placed in five layers, compacted in the standard CBR mould, and placed in the CBR apparatus at a 1.25 mm/min loading rate. Upon loading, the sample will give displacement and load resistance in the data acquisition system.
The methodology outlined above will provide comprehensive data and insights into the utilization of mine-overburdened materials reinforced with coconut coir geotextile for low-volume road construction, ensuring the development of cost-effective, environmentally friendly, and sustainable road infrastructure.

4 Results and discussion

The outcomes of the Modified Proctor Test (MPT), specifically the OMC and MDD, are illustrated in the accompanying **Figure 8.** The figure demonstrates a notable contrast in OMC and MDD values between the conditions before and after the application of CGT in the test sample. Prior to the utilization of CGT, the OMC and MDD were recorded at 6% and 2.84 g/cc, respectively. Post the incorporation of CGT, these values shifted to 7.4% for OMC and 2.89 g/cc for MDD, as depicted in Figure 8.

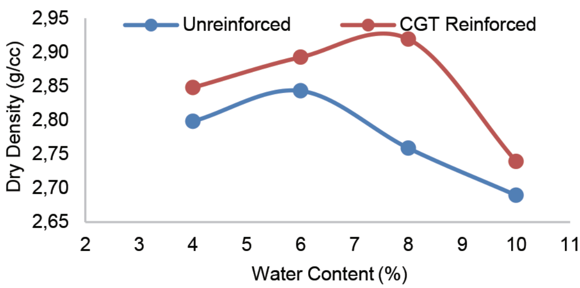

Figure 8 Comparison of Unreinforced and CGT-reinforced MPT

The California Bearing Ratio (CBR) mould was compacted at the Optimal Moisture Content (OMC) and Maximum Dry Density (MDD) obtained from the modified Proctor test for both unreinforced and Coir Geotextile (CGT) reinforced samples. The test results are graphically depicted in Figures 9 and 10.

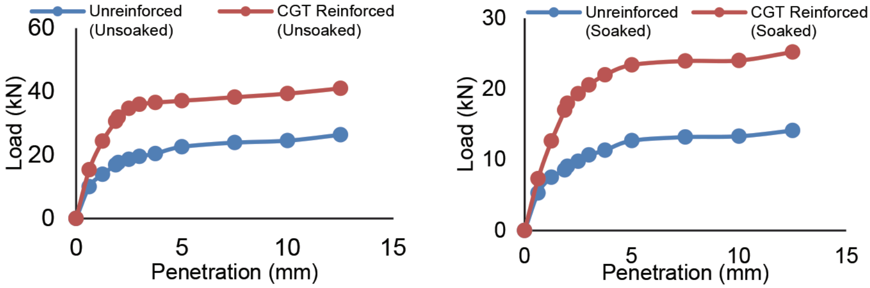

Figure 9 Graphs showing results of unreinforced and CGT reinforced CBR results for soaked and unsoaked condition

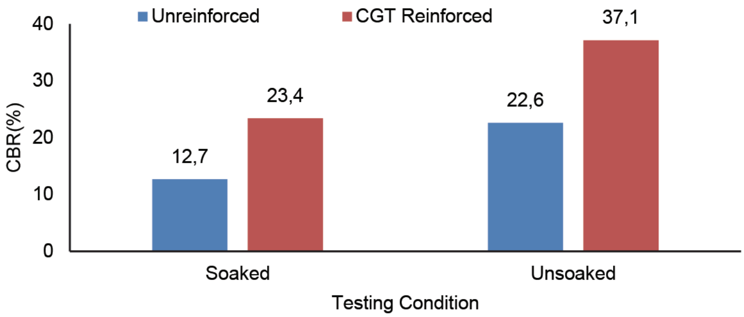

Figure 10 Graph showing the variation of CBR before and after CGT reinforcement application

The findings indicate a notable enhancement in the CBR value when CGT reinforcement is applied, demonstrating a 1.84 times improvement under soaked conditions and a 1.64 times improvement under unsoaked conditions. As the coir's water-holding capacity is greater, the rate of increase in the soaked condition is higher than in the unsoaked condition. This means that if coir is used in the subbase layer as a reinforcement, it will increase the strength of the pavement.

5 Conclusion

This research focuses on enhancing the strength properties of mine overburden aggregates (MOMs) by substituting them for virgin aggregates in the subbase or base layer of pavement sections and reinforcing them with coir geotextile. CBR tests were conducted for both with and without coir geotextile reinforcement, along with their respective OMC and MDD determinations. The unreinforced MOMs exhibited a CBR of 12.7%, failing to meet the minimum criteria outlined in IRC SP:72 (2015). To enhance load-bearing capacity, reinforcement was introduced in the form of coir geotextile. The CBR of the reinforced coir geotextile was 23.4%, meeting the minimum requirements specified in IRC SP:72 (2015).
This study underscores the potential of using MOMs and CGT in low-volume roads as a sustainable construction approach. However, further large-scale studies are needed to support additional parametric investigations before recommending inclusion in codal provisions.

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