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STABILIZATION OF LATERITIC SOIL USING RECYCLED PLASTICS

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KeyWords

Atterbergs limit, California Bearing Ratio, compaction, lateritic soil, proctor, recycled plastic, soil stabilization.

ABSTRACT

Many rural roads in Kenya are surfaced with lateritic soil, which often has low strength and is prone to deterioration in wet conditions [1]. Simultaneously, plastic waste accumulation presents a major environmental problem. This study investigates using shredded recycled plastic as a stabilizer for lateritic soil to enhance road durability, building upon global frameworks for synthetic waste reuse in civil engineering applications [2] [3]. Lateritic soil samples from Eldoret were mixed with cleaned, shredded PET flakes at 0%, 2%, 4%, 6%, and 8% by weight. Standard laboratory tests; modified Proctor compaction and California Bearing Ratio were performed on each mix. Atterberg Limits was also conducted to help classify the soil. The plastic–soil composite showed changes in compaction behavior and strength. Increasing plastic content tended to raise the Optimum Moisture Content while reducing the Maximum Dry Density. Moderate plastic additions can yield distinct variations in load-bearing capacity compared to pure lateritic soil, as indicated by fluctuating CBR values, whereas excessive plastic content can drastically reduce the interlocking capacity of granular materials **[4]**. The treated mixes appeared more resistant to moisture and exhibited reduced stiffness under specific structural limits. It is unadvisable to use in high load bearing roads. Incorporating recycled plastic into lateritic soil remains a promising environmental stabilization approach. It helps recycle waste and can alter road performance, supporting sustainable infrastructure goals **[5]**Further study of long-term durability and environmental impact is recommended.

INTRODUCTION

The challenge of managing plastic waste and maintaining durable murram roads has drawn increasing attention in the civil engineering field due to its environmental and infrastructural significance. Plastics are widely used in packaging, household items, and industrial products because of their low cost, strength, and versatility. However, their non-biodegradable nature leads to severe environmental pollution when disposed of improperly. In Kenya, a large proportion of plastic waste ends up in dumpsites, water bodies, and drainage systems, causing blockages, flooding, and harm to wildlife. At the same time, most rural access roads in the country are made of lateritic soil, which is prone to erosion, deformation, and dust generation. These roads have become difficult to maintain, especially during the rainy season, leading to poor connectivity and increased transport costs.

Various researchers across the world have explored innovative ways of recycling plastic waste into construction materials. Studies in India showed that incorporating waste plastic into bituminous mixes improved road durability, flexibility, and resistance to water damage [6]. Similarly, it was demonstrated that plastic-coated aggregates in flexible pavements increased the binding properties and reduced pothole formation. While these studies primarily focused on bituminous or asphalt roads, a few researchers have recently extended this idea to unpaved or murram roads. For instance, Kenya investigated the mechanical improvement of soil when mixed with shredded plastic waste, observing enhanced California Bearing Ratio values and reduced water absorption [5]. Additional laboratory findings demonstrate that varying forms of plastic waste strips and non-cohesive synthetic fibers can yield highly diverse effects on the California Bearing Ratio (CBR), hydraulic conductivity, and basic engineering properties of silty and expansive soil matrices [7]

The two areas of focus on plastic waste management and road stabilization are closely linked. Plastic waste recycling offers an opportunity to mitigate pollution while improving the performance of low-cost road networks. By integrating shredded plastic into murram, the resulting mixture is expected to exhibit improved cohesion, enhanced water resistance, and increased load-bearing capacity. This dual benefit makes the concept both environmentally and economically viable. However, the practical application of plastic-stabilized murram roads in Kenya remains limited, with a need for more localized studies to determine the optimal plastic content and its behavior under different soil conditions [1]. Understanding the fundamental concretionary properties and structural mechanics of these base materials is vital before field execution [8]. This study, therefore, seeks to build upon previous research by evaluating the suitability of using plastic waste to stabilize murram soil for road construction under Kenyan condition [9].

Materials and Methods

1. Lateritic Soil and Plastic Materials

Lateritic soil was sourced from a local borrow pit named Sergoit Quarry near Eldoret, Kenya. The soil was air-dried and sieved to remove coarse debris. Basic soil classification was performed to characterize untreated soil. Shredded plastic was obtained by collecting waste polyethylene terephthalate bottles, washing them, and cutting or shredding them into flakes of approximately 1-2 mm [2]. The shredded PET, which is non-plastic and non-clay, served as the stabilizing additive.

2. Sample Preparation

The lateritic soil and shredded PET were thoroughly mixed by weight to create composites with plastic content of 0% (control), 2%, 4%, and 6%. Each batch was homogenized to dry, then water was added to reach target moisture contents for compaction and CBR tests. Prior to testing, the mixtures were sealed to equilibrate moisture. A sample of lateritic soil is shown in Figure 1.

Figure 1: Lateritic Soil

I) Sieve Analysis

The physical grading of the raw murram was determined through a mechanical sieve analysis conducted in accordance with BS 1377-2:1990 [10]. A representative 6000g oven-dried sample was processed through a nested series of sieves ranging from 28 mm down to 0.075 mm to determine the relative proportions of gravel, sand, and fines. From the resulting gradation curve, the Coefficient of Uniformity Cu and Coefficient of Curvature Cc were calculated.

II) Proctor Compaction Test

A modified Proctor test was performed on each soil–plastic mix to determine the Maximum Dry Density and Optimum Moisture Content. Specimens were compacted in a standard mold at several moisture contents, and the wet density was measured. Dry density and moisture curves were plotted for each mix. From these curves, the OMC and corresponding MDD were obtained.

III) California Bearing Ratio Test

CBR tests were conducted on compacted specimens of each mix according to standard procedures. Each sample was loaded by a standard penetration piston, and the load at 2.5 mm (about 0.1 in) penetration was recorded. The CBR value was calculated for each mix. This index indicates the load-bearing capacity of the stabilized soil.

IV) Atterberg Limits

Liquid limit and plastic limit were performed on the natural lateritic soil without plastic to determine its Atterberg limits and plasticity index, PI = LL – PL. These tests classify the soil's consistency and swelling potential. After plastic addition, the effective PI of the composite is reduced due to the non-plastic nature of the PET, which is expected to diminish volumetric changes.

Results and Discussion

Compaction Test Results

The compaction properties of the murram-plastic mixture exhibited a clear downward trend in density as the plastic content increased from 0% to 6%. The Maximum Dry Density (MDD) decreased linearly from 2.070 Mg/m^3

to 1.650 Mg/m^3, a variation primarily attributed to the lower specific gravity of the recycled plastic compared to the heavier lateritic soil particles it replaced. While the Optimum Moisture Content (OMC) initially dipped to 13.80% at 2% plastic inclusion, likely due to the non-absorbent nature of the synthetic material, it subsequently rose to 18.20% at the 6% mark. This rise in OMC suggests that at higher concentrations, the plastic fragments created larger interstitial voids within the soil matrix, requiring additional water to lubricate the particles enough to achieve the maximum possible compacted state. These results indicate that increasing plastic content significantly reduces the unit weight of the fill, which may be advantageous for lightweight embankments but suggests a loss of solid soil-to-soil contact.

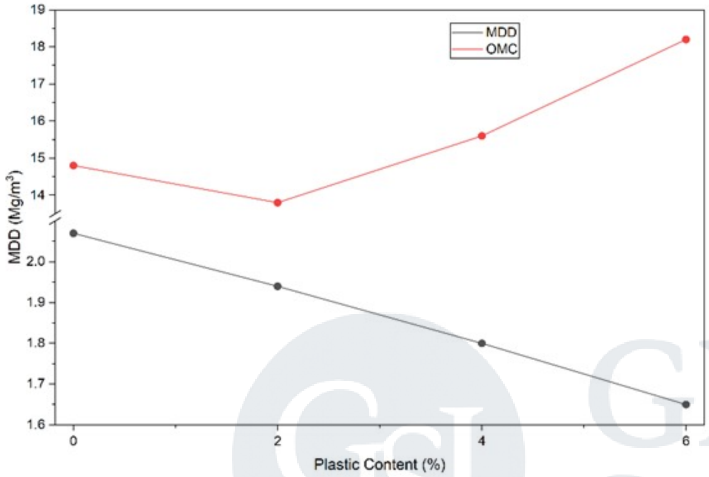

Figure 2: OMC and MDD of lateritic soil with plastics in %

Table 1: Summary of Results

Plastic content (%)	**MDD (Mg/m3)**	**OMC (%)**	**CBR (Soaked)**	**%Change in CBR**	**Suitability**
0	2.070	14.80	42	0	Base/Sub-base
2	1.940	13. 80	10.5	-75	Subgrade
4	1.800	15.60	8.5	-79.76	Improved subgrade
6	1.650	18.20	6.8	-83.89	Fill material

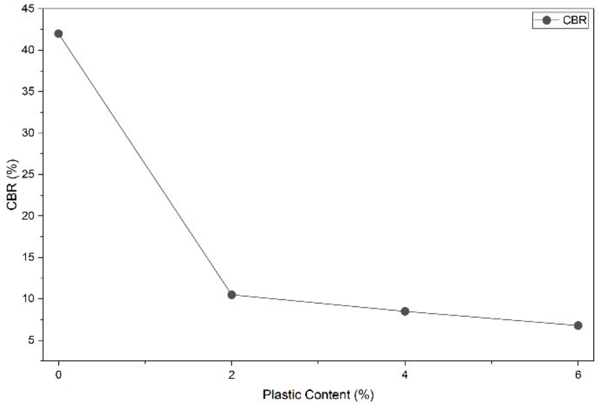

Figure 3: Summary of CBR results

The California Bearing Ratio (CBR) results revealed a drastic and immediate reduction in the structural strength of the murram upon the introduction of recycled plastic waste.

As shown in Figure 6, the control sample, 0% plastic, yielded a robust CBR of 42%, which is typically suitable for road base or sub-base layers; however, this value dropped by 75% to just 10.5% CBR with the addition of only 2% plastic. As the plastic content reached 6%, the CBR dropped further to 6.8%, representing a total strength loss of 83.89% relative to the natural soil. This deterioration in bearing capacity indicates that the smooth-surfaced plastic particles likely acted as slip planes, interfering with the internal friction and mechanical interlocking of the murram grains. Consequently, while the plastic-modified soil remains a viable option for non-structural fill or improved subgrade in low-traffic areas, it becomes entirely unsuitable for the main load-bearing layers of a flexible pavement. Figures 7, 8 and 9 shows CBR trends for 2%, 4% and 6% respectively.

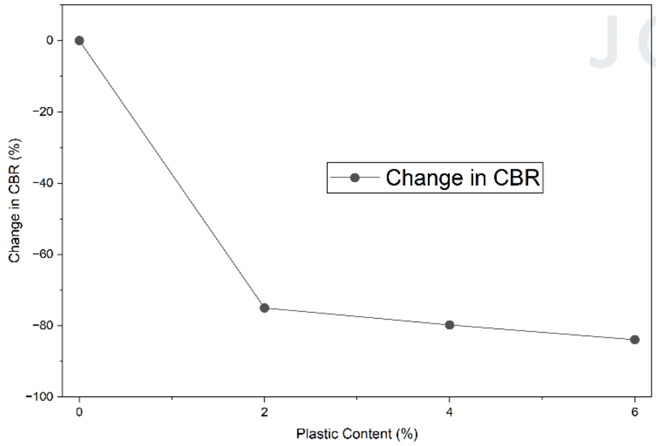

Figure 4 :% Change in CBR

CBR Penetration results

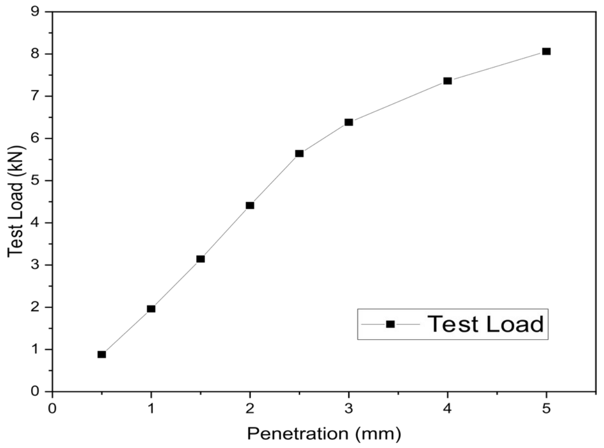

Figure 5: Control Test (0% Plastic)

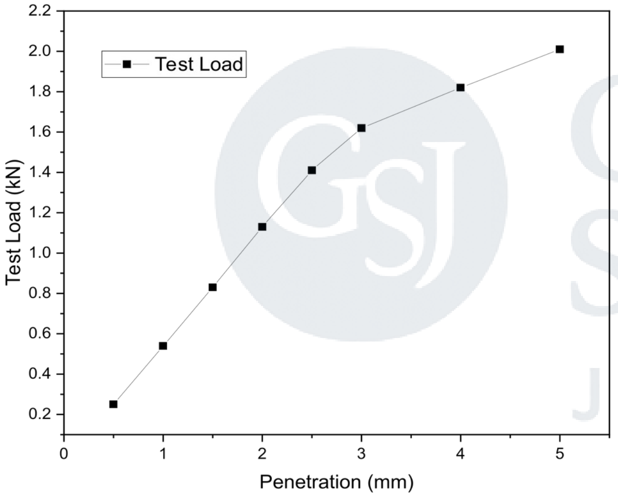

Figure 6: 2% Plastic-Stabilized Soil

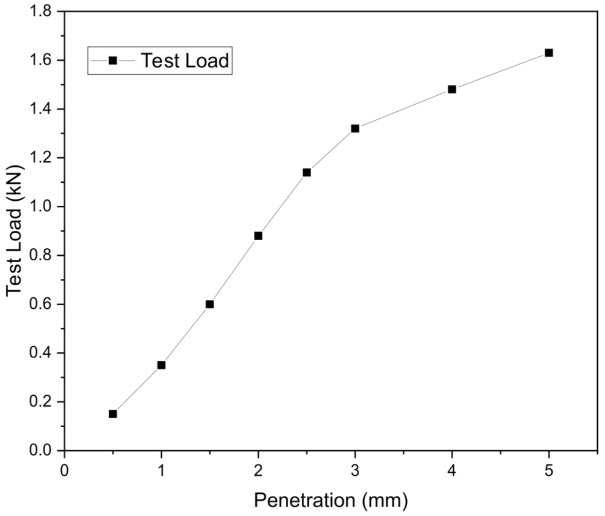

Figure 7: 4% plastic-Stabilized Soil

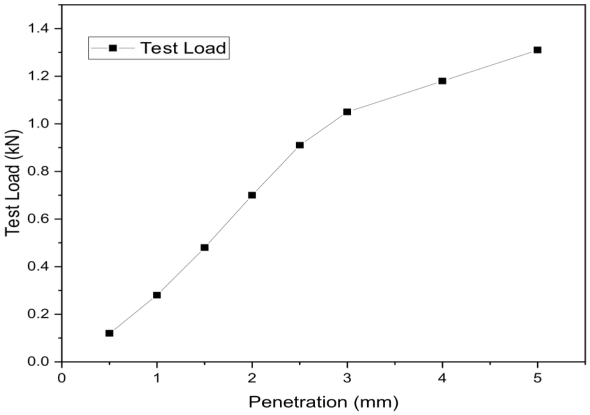

Figure 8: 6% Plastic-Stabilized Soil

The penetration curves indicate a clear inverse relationship between PET content and the structural stability of the murram soil, where the load-bearing capacity significantly diminishes as the percentage of plastic waste increases. The control sample (0% PET) exhibits the highest resistance to penetration, likely due to the natural interlocking and dense packing of the murram grains. However, the introduction of PET, starting at just 2%, causes a sharp decline in the load required to reach standard penetration depths, suggesting that the smooth, non-cohesive plastic particles interfere with the internal friction and soil-to-soil contact of the mixture. As PET concentration rises to 4% and 6%, the further reduction in strength implies that the plastic acts more as a structural void or a lubricant than a reinforcing agent, potentially increasing the elasticity and compressibility of the matrix.

Sieve Analysis

The particle size distribution of the natural murram, as detailed in the sieve analysis data, identifies the material as a well-graded sandy Gravel according to the British Standard (BS EN ISO 14688-1) and an A-1-a soil under the AASHTO M 145 system [11]. The gradation curve is characterized by a Cu (Coefficient of Uniformity) of 15.45 and a Cc (Coefficient of Curvature) of 0.94, values which confirm a well-distributed range of particle sizes essential for high-density compaction. A critical observation from the analysis is the exceptionally low percentage of fines, only 1.31% passing the 0.075 mm sieve, which classifies this as a clean granular laterite with high permeability and excellent drainage characteristics.

The "A-1-a" classification signifies a premium engineering material typically reserved for high-load applications such as road base and sub-base courses. The dominance of stone fragments and gravel-sized particles provides a stable skeleton that relies on mechanical interlocking for its strength as evidenced by the high control CBR of 42%. In the context of this study, the high quality of natural soil makes it particularly sensitive to the introduction of non-cohesive additives like recycled plastic. Because the natural soil relies on the tight interlocking of these well-graded gravel and sand particles, the introduction of plastic likely disrupted this "stone-to-stone" contact, explaining the sharp decline in CBR values observed in subsequent tests. By establishing that the base material is of "premium" grade, the study highlights that even high-quality concretionary laterites can have their structural integrity compromised by improper plastic-waste stabilization ratios. The sieve analysis results are shown in Figure 10.

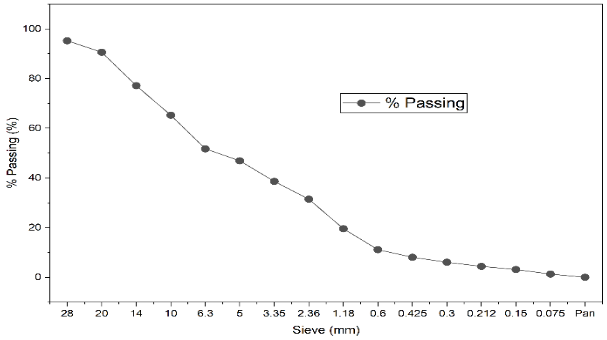

Figure 9: Sieve Analysis Results

Atterberg Limits

Liquid limit was 14.80%, Plastic Limit was 9.30%, therefore Plasticity Index was found to be 5.50%. The low Plasticity Index is a critical indicator of the soil's high structural quality. This value confirms a low expansion potential, which is directly validated by the minimal experimental swell value of 0.15% recorded during soaking.

These results reinforce the A-1-a (AASHTO) classification, as a PI below 6% is typical for premium granular materials that rely on mechanical interlocking rather than clay cohesion for strength. Because the natural murram lacks a strong plastic "binder," the introduction of smooth PET shreds likely disrupted the internal friction of the gravel skeleton, leading to the significant reduction in bearing capacity observed in the CBR tests.

Conclusion

This research investigated the mechanical and physical implications of stabilizing high-quality, well-graded lateritic sandy gravel (A-1-a) with 1 mm shredded PET waste at concentrations of 2%, 4%, and 6%. The study concludes that while recycled plastic serves as a viable environmental sequestering agent, its inclusion in premium granular murram triggers a significant "lubrication effect" that disrupts the critical stone-to-stone interlocking of the soil matrix. This was evidenced by a linear reduction in Maximum Dry Density from 2.070 Mg/m³ to 1.650 Mg/m³ and a drastic 83.89% total decrease in CBR values, which dropped from a control of 42% to just 6.8% at the 6% inclusion level. Furthermore, the increase in Optimum Moisture Content to 18.20% at higher plastic concentrations suggests that the hydrophobic nature of the PET shreds creates larger interstitial voids, potentially compromising water resistance in dense pavement layers. Consequently, while this composite offers a sustainable solution for reducing plastic litter in streets and gutters, its structural limitations render it unsuitable for road base construction, restricting its engineering application to only low-load environments such as pedestrian walkways or erosion-control fill.

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