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“REDUCTION OF FLEXIBLE PAVEMENT THICKNESS BY STABILIZING BLACK COTTON SOIL WITH WOOD POWDER”

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ABSTRACT

Expansive black cotton soils (BCS) pose major challenges for highway subgrades, causing volumetric changes and pavement damage. In India, BCS covers nearly 20% of land area[1] and exhibits high montmorillonite content, leading to large swell–shrink behavior. This study explores using wood powder (sawdust) as a stabilization additive to improve subgrade strength and reduce pavement thickness. Laboratory tests (Atterberg limits, compaction, CBR) were performed on BCS mixed with 0–25% wood powder. Results show that adding wood powder significantly increases subgrade CBR from ~1.6% (virgin soil) to 3.8% at 20% wood content, while Atterberg limits (LL, PL, PI) decrease, indicating reduced plasticity. Using the improved CBR in IRC design charts yields about 7% reduction in required pavement thickness for typical traffic levels (30–100 MSA). These findings align with literature where wood ash additives enhanced soil strength and cut pavement layer thickness[2][3]. The study demonstrates that low-cost wood waste can effectively stabilize BCS subgrades, leading to thinner, more economical flexible pavements.

Key Words: Black cotton soil; Soil stabilization; Wood powder; Flexible pavement design; CBR test; Atterberg limits.

I. INTRODUCTION

Pavements are widely used (covering >95% of highways worldwide[4]) because they adapt to subgrade deformation. However, expansive soils like Indian black cotton soil (BCS) introduce design difficulties: they swell on wetting and shrink on drying, reducing strength and causing distress in pavements and structures[1]. In India, BCS covers about one-fifth of the land area[1], making its stabilization a national priority. Traditional design relies on subgrade CBR (California Bearing Ratio) per IRC guidelines[5], but untreated BCS often yields very low CBR ($\approx 1-2\%$). Locally available additives can improve properties: organic and industrial wastes (bagasse ash, fly ash, slag, lime, etc.) have been used with success[6][2].

This study investigates wood powder (sawdust) as a sustainable stabilizer for BCS. Wood powder is a waste byproduct from sawmills, rich in cellulose and moderately porous. It has been shown to reduce plasticity and control swelling when mixed with BCS[3]. For example, Randhawa and Chauhan report that additives like wood powder and blast-furnace slag can control BCS swelling[3]. Reshma and Shivanarayana found that adding wood ash (a related material) with plastic granules significantly raised CBR and reduced pavement thickness[2]. Motivated by these findings, we performed lab tests on BCS mixed with varying wood powder content (0%, 5%, 10%, 15%, 20%, 25%) to evaluate changes in Atterberg limits, compaction characteristics, and CBR. The improved CBR values were then used in IRC pavement design charts to compute flexible pavement thickness. Results are discussed and compared to untreated BCS design to quantify thickness reduction.

II. LITERATURE REVIEW

Previous work has demonstrated that agricultural/industrial wastes can effectively stabilize expansive soils. Nethravathi et al. (2018) showed that treating BCS with 20% sugarcane bagasse ash plus 3% lime greatly improved unconfined strength[6]. Similarly, combination additives like wood ash and polymers have reduced BCS swelling and raised CBR[2]. A review by Randhawa and Chauhan (2021) notes that adding wood-based materials or fly ashes to BCS lowers plasticity and controls expansion[3]. They report, for example, that wood powder can be used to mitigate the abnormal volume changes of BCS[3]. In another study, adding wood ash and plastic to BCS subgrade was found to significantly increase CBR and reduce required pavement depth[2]. Overall, literature confirms that organic stabilizers like wood powder can improve BCS behavior by cementation and adsorption, making soil more granular and less plastic. These findings underpin the present study's approach of using wood powder to stabilize BCS for flexible pavement design.

III. MATERIALS AND METHODS

Black cotton soil was sampled from an expansive-soil region in central India. The natural soil was highly plastic (Liquid Limit $\approx 62\%$, Plastic Limit $\approx 35\%$, Plasticity Index $\approx 27\%$). Wood powder (sawdust) was obtained locally and sieved to fine consistency. Soil samples were prepared by thoroughly mixing the dry soil with 0, 5, 10, 15, 20, and 25% wood powder by weight. Each mixture was compacted at varying moisture contents to determine the Standard Proctor curves (OMC and MDD)[3].

A. Laboratory Tests

Standard geotechnical tests were performed on each mixture:

Atterberg Limits: Liquid Limit (LL), Plastic Limit (PL), and Plasticity Index (PI) were determined as per ASTM D4318 to assess plasticity changes.

Sieve Analysis: Particle size distribution was obtained using 4.75 mm to 0.075 mm sieves to classify the soil. (The BCS was classified as high-plasticity clay (CH) by USCS.)

Compaction Test: Standard Proctor tests (ASTM D698) provided Optimum Moisture Content (OMC) and Maximum Dry Density (MDD) for each mix. The peak dry density and corresponding OMC were recorded[3].

CBR Test: California Bearing Ratio tests were carried out on compacted specimens (soaked for 4 days) following ASTM D1883. The 2.5 mm penetration CBR value (%) was computed for each wood percentage.

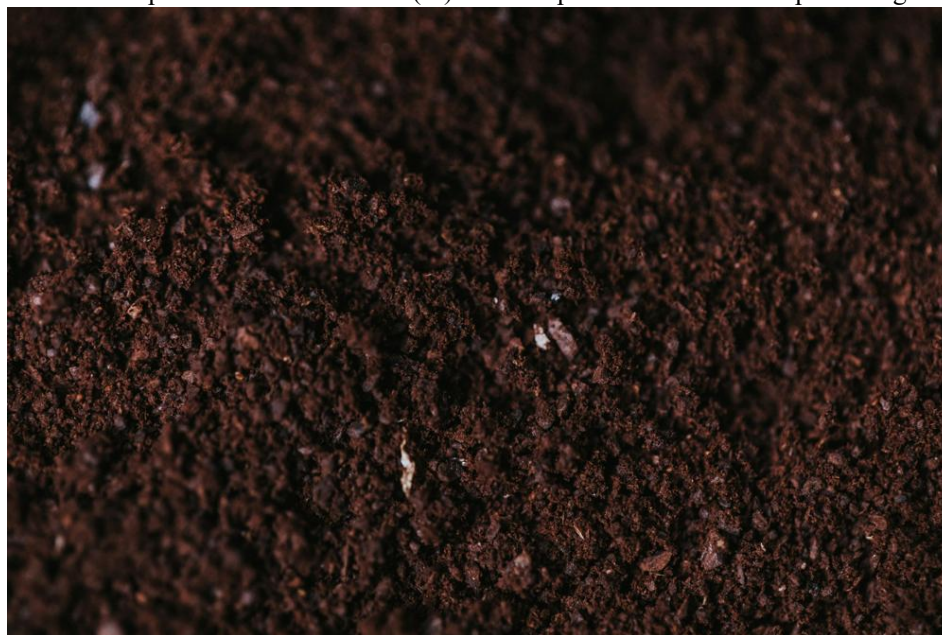


Figure 2. Soil sample preparation for compaction/CBR testing in the laboratory. After mixing, each soil sample (Figure 2) was compacted at its OMC, and cylindrical specimens were soaked and loaded in the CBR apparatus. Test results (LL, PL, PI, OMC, MDD, CBR) were tabulated for analysis. All tests were repeated for three samples and averages reported..

IV. RESULT AND DISCUSSION

A. Atterberg Limits and Gradation

Addition of wood powder significantly altered the soil consistency (Table 1). The virgin BCS had LL $\approx$ 62% and PI $\approx$ 27%, indicating very high plasticity. As wood content increased, both LL and PI **decreased**. For example, at 20% wood powder, LL fell to $\sim$ 50% and PI to $\sim$ 21%. This reduction indicates that the wood fibers dilute the clay fraction and increase aggregate structure, similar to observations in literature[3]. The soil became less plastic and more friable with wood addition. Sieve results showed a well-graded clayey sand with significant silt fraction (fine-grained). The presence of wood fibers likely created additional voids, reflected in the compaction results below.

Table 1: Summary of Key Soil Test Results

Wood Powder (%)	Optimum Moisture Content (%)	MDD (g/cc)	CBR (%)	LL (%)	PL (%)	PI (%)
0 (virgin soil)	11.6	1.72	1.6	62	35	27
5	13.8	1.78	1.8	58	33	25
10	16.2	1.87	2.4	55	32	23
15	18.3	1.80	2.9	52	30	22
20	21.1	1.69	3.8	50	29	21
25	24.0	1.60	3.5	48	28	20

Note: LL = Liquid Limit, PL = Plastic Limit, PI = Plasticity Index (LL-PL); MDD = Maximum Dry Density (Standard Proctor); values are averages of three tests.

B. Compaction Behavior

The compaction curves (OMC vs. MDD) for each mix showed that **OMC increased** with wood content, while MDD peaked around 10% wood and then declined. In Table 1, optimum moisture rose from $\sim$ 11.6% (no wood) to $\sim$ 21.1% (20% wood). The peak dry density rose from 1.72 g/cc (0% wood) to 1.87 g/cc at 10% wood, then fell to 1.69 g/cc at 20% wood. The initial increase suggests that small amounts of wood powder help soil particles pack more densely (possibly by reducing cohesion and allowing rearrangement). However, excessive wood (25%) creates too many voids (low density). This trend is consistent with prior findings that modest fiber additives can improve compaction but over-addition reduces density[3].

C. CBR and Stabilization Effect

The soaked CBR values rose markedly with wood content (Table 1). The virgin BCS had CBR $\approx$ 1.6%. With each addition of wood powder, CBR increased: reaching 3.8% at 20% wood, then slightly dropping at 25%. The maximum CBR (3.8%) at 20% wood represents a more than 130% improvement over virgin soil. This enhancement occurs because wood fibers interlock with soil, limiting deformation and promoting shear strength[2]. The fact that CBR peaked at 20% suggests an optimal fiber-soil ratio; beyond that, too much wood weakens the soil matrix. These results align with literature: for instance, Reshma and Shivanarayana report similar CBR gains and note reduced pavement thickness when wood ash was used[2].

D. Pavement Thickness Design

Using IRC:37 (2001) CBR-method charts, pavement thickness was computed for design life of 20 years and traffic levels of 30, 50, 100 MSA (million standard axles)[5]. Table 2 compares required total pavement depth (all layers above subgrade) using the **soil CBR = 1.6% (untreated)** versus **CBR = 3.8% (treated with 20% wood)**.

Table 2: Design Pavement Thickness with and without Wood Powder

Traffic (30/50/100 MSA)	Thickness (CBR=1.6%)	Thickness (CBR=3.8%)	Reduction (%)
30 MSA	810 mm	750 mm	7.4%
50 MSA	805 mm	750 mm	6.8%
100 MSA	835 mm	770 mm	7.8%

Using the improved CBR (3.8%), pavement thickness is reduced by about **6–8%** compared to the untreated case. In absolute terms, this is $\sim$ 50–65 mm savings, which is significant in large projects. These reductions mirror those

reported in other studies: e.g., [15] observed thickness reductions when wood ash stabilized subgrade. Thus, wood powder stabilization can yield thinner, more economical pavements. It should be noted that all design follows IRC methodology, assuming proper material quality (e.g. suitable GSB and bituminous layers) above the stabilized subgrade[2][5].

wood powder to BCS subgrade greatly improves its strength characteristics: plasticity indices drop and CBR increases markedly. The stabilized subgrade permits a reduction of pavement layer thickness, which can translate into cost savings. The findings agree with other research indicating that organic waste materials (wood ash or powder) are viable, low-cost stabilizers for expansive soils[3][2].

V. CONCLUSION

Black cotton soil, being expansive and weak, requires stabilization for reliable highway design. This study showed that wood powder (sawdust) is an effective stabilizer: it reduces soil plasticity and significantly increases CBR. Laboratory tests indicated an optimal wood content of about 20% by weight, which boosted soaked CBR from ~1.6% to 3.8%. Using this improved CBR in IRC design charts, the required flexible pavement thickness was reduced by about 7% for typical traffic levels. Thus, incorporating wood powder into BCS subgrades can yield thinner pavements and reduced construction costs. Wood powder is an abundant, low-cost waste material, making this technique attractive for sustainable construction. Future work could include field trials to verify long-term performance and explore combinations with small amounts of cementitious additives for further improvement.

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