

UTILIZATION OF WOOD DUST AS A SUSTAINABLE ADDITIVE IN ROAD CONSTRUCTION FOR SMART AND GREEN INFRASTRUCTURE

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ABSTRACT

Malaysia's Public Works Department (JKR) estimates that over 60% of road construction materials consist of aggregates, sourced primarily from riverbeds, hillsides, and quarries. This reliance on non-renewable natural resources has resulted in serious environmental consequences, including deforestation, soil erosion, and biodiversity loss. Innovative green engineering solutions are one of the initiatives in reducing environmental impacts through the use of recycled materials. The use of recycled materials as additives in construction materials has the potential to reduce complete dependence on natural resources, especially in road construction engineering. This study was conducted to see whether wood sawdust can be used as an environmentally friendly additive in the subgrade layer of road pavement. The use of this waste wood sawdust was studied to see whether the road base layer mixed with wood sawdust can help reduce complete dependence on the natural soil layer. This study also aims to support green engineering through the use of industrial recycled materials. Soil samples in the laboratory were mixed with wood sawdust waste at a certain rate to evaluate the performance of each wood sawdust and soil mixture. The California Bearing Ratio (CBR) and Standard Proctor Compaction Test (SPCT) were conducted. The purpose of the test was to determine the Maximum Dry Density (MDD), Optimum Moisture Content (OMC), and the bearing capacity (CBR) of the subgrade soil layer in road pavement design. Findings showed that a combination of 5-10 percent of wood sawdust can enhance compaction and moisture control. While a mixture exceeding 10% will reduce the bearing capacity of the soil. Through this study, it can be shown that the use of industrial wood dust can be used as an additive in the construction of road base layers and is suitable for application on low-traffic roads. The use of this wood waste material also supports the use of industrial waste recycling and helps reduce the carbon footprint in road construction towards innovative green engineering products.

1.0 Introduction

Malaysia remains committed to upgrading of existing routes and building new roads, in line with national development plans in the 13th Malaysia Plan (Bernama, 2025). The continuous expansion of road infrastructure in Malaysia contributed to the increasing demand for natural aggregates used in subgrade construction. Moreover, the cost of aggregate materials has increased due to quarrying restrictions and rising transportation costs, especially in rural and East Malaysian regions (CIDB, 2022; DOSM, 2023). This reliance on non-renewable natural resources has resulted in serious environmental consequences, including deforestation, soil erosion, and biodiversity loss (DOE Malaysia, 2022).

On the other hand, Malaysia produces a significant volume of wood waste, primarily from the timber processing and furniture manufacturing industries. The Malaysian Timber Industry Board (MTIB) reported that over 1.3 million tonnes of wood residues are generated annually. In line with Sustainable Development Goal (SDG) 12 Responsible Consumption and Production, the reuse of wood dust as a construction material aligns with the circular economy model and the 3R (Reduce, Reuse, Recycle) principles.

Several studies have investigated the incorporation of organic or industrial by-products in soil stabilization. Butt et al. (2016) reported that their experimental study revealed that the addition of sawdust ash to clayey soil significantly increases CBR and unconfined compressive strength. Similarly, Herman et al. (2017) conducted research that showed that the CBR value of native soil with the addition of 6% sawdust ash can increase the CBR value of clay soil. The CBR value is greatly improved with the addition of sawdust (Sharma, 2021). Research conducted in Indonesia examined the geotechnical properties of the expansive soil stabilized with the addition of percentages between 3 and 7% of Keruing sawdust, showing improved soil geotechnical properties by reducing plasticity index, but increasing unconfined compressive strength and CBR (Niyomukiza et al. 2020). Sawdust, as a by-product of wood processing, has a rough texture that can generate high friction between the fiber and the matrix of the soils, leading to a significant increase in its shearing strength and bearing capacity (Medina, 2023). However, research on the direct use of raw wood dust (not ash) in subgrade applications remains limited, especially in tropical climates where moisture content plays a critical role in soil behavior

The subgrade layer is a natural soil fill that functions as a load-bearing layer in road construction. The mining of hill soil to obtain natural subgrade soil is an issue that contributes to landslides and floods. Therefore, the reuse of industrial waste such as sawdust as an environmentally friendly additive in the construction of the subgrade layer can help reduce waste and complete dependence on natural soil resources. There are several studies on the use of wood powder as an additive in civil engineering. According to a study by Nor Hazian (2024), industrial waste such as sawdust has the potential to be regenerated for innovative, sustainable alternative material products. Meanwhile, a study by Maria (2008) also shows that sawdust has the potential to be used as a curing agent in concrete mixtures. This material also has advantages when used as an additive with other mixtures, such as in the production of tiled roofs (Che Hasnah, 2017). The aim of the research is to determine the possibility of utilizing sawdust waste as a sustainable additive in enhancing engineering properties, particularly the

load-bearing capability of subgrade soil during road construction. This study also supports government efforts to increase green engineering innovation and sustainable infrastructure.

Objective

The research goal is to determine the feasibility of using sawdust waste as a sustainable additive to improve the engineering properties, particularly the load-bearing capability of subgrade soil during road construction.

2.0 Methodology

Research methodology conducted through an experimental approach in the Road Engineering Laboratory to test the bearing capacity of the subgrade soil incorporating sawdust waste additives. The study was conducted using the best samples of soil and sawdust, including dust in the laboratory. A series of four samples of soil mixtures, with sawdust waste percentages of 0%, 5%, 10% and 15% was prepared. Every sample of soil mixture weighed 6 kilograms. Standard Proctor compaction test and California Bearing Test (CBR) test were carried out in this experiment. Standard Proctor compaction test with a sample immersion time of 0 days according to the procedure (ASTM D-1557) was carried out to identify the optimum moisture content (OMC) and maximum dry density (MDD). Mixture samples were compacted (Standard Proctor Compaction Test; Standard Proctor 1963) to OMC and MDD readings. Meanwhile, the CBR test was to be conducted to find out the load-bearing capacity in accordance with the ASTM D1883 standard and with reference to the provisions of the Malaysian Standard Road Specification JKR/SPJ/1998.

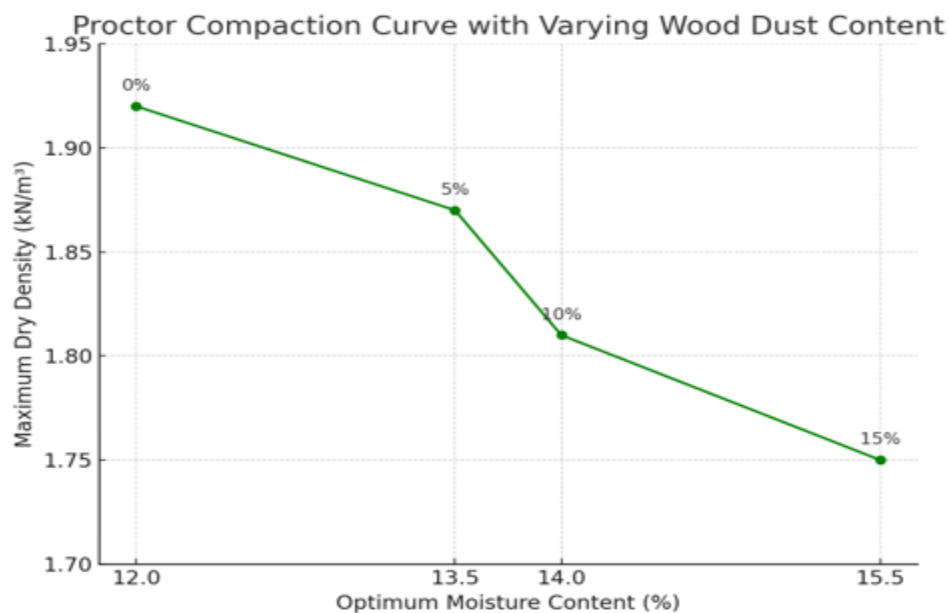
3.0 Result

The results of the Proctor compaction test analysis in Table 1 show that the maximum dry density for the 15% mixture content decreased by 1.75kN/m^3 compared to the 0% mixture, which was 1.92kN/m^3 . The optimum moisture content increased from 12.0% to 15.5%. This finding shows that as the percentage of dust increases, there is a decrease in density (MDD) and an increase in high water absorption (OMC) in the soil and sawdust mixture compared to natural soil. This means more water will be needed for the compaction work. Meanwhile, for the 5% and 10% sawdust mixture content, the performance of MDD and OMC is still within the acceptable range. Figure 1 shows the graph of the MDD and OMC test results.

The CBR test also decreased by 12.4% for the 15% sawdust mixture content. This indicates that the addition of large amounts of wood waste additives to natural soil can reduce the strength and cohesion of particles, thereby reducing the load-bearing capacity of the soil. The CBR test results in Table 1 show the mixture ratio of natural soil and sawdust that meets the minimum CBR standard of JKR, which is 5%-12% for low-volume roads suitable for village roads.

Table 1: Data of Standard Proctor compaction test and California Bearing Ratio (CBR) test

Wood dust (%)	MDD (kN/m)	OMC (%)	CBR (%)
0	1.92- Stable	12.0	16.5
5	1.87- Stable	13.5	18.2
10	1.81- Descending	14.0	19.0
15	1.75- Low	15.5	12.4



Graph 1: Result of MDD and OMC test

4.0 Discussion

Test results have revealed that, in addition, there are large differences in the compaction properties of wood sawdust to soil mixtures. This decrease was due to the lower relative density of wood sawdust compared to mineral soil, due to the presence of organic matter that absorbs water and reduces the bulk mass of the mixture. Although the increase in OMC can have a positive effect on maintaining moisture in the soil layer. The decrease in MDD can affect the support strength if not controlled. However, at the addition rates of 5% and 10%, this change is still within the acceptable range and can provide benefits in terms of workability and water control. Therefore, this analysis shows that the addition of wood sawdust in the moderate range (5%-10%) is optimal in terms of compaction properties according to the Standard Proctor test. The CBR of subgrade materials, as given in the JKR/SPJ/1988 Standard Specification on road construction, is 30 %. Amendment to the Road Technique Instructions, ATJ 5/85 (Amendment 2013) allows a minimum CBR value of 5% for the construction of roads with low vehicle capacity, such as village roads. This means that a 5% wood sawdust mixture can be used to increase the soil load-bearing capacity and soil compaction values for low-capacity roads.

5.0 Conclusion

Although the use of sawdust in subgrade soil mixtures cannot be used in maximum quantities, this study confirms that sawdust waste has the potential as a sustainable additive in improving the engineering characteristics, especially the load-bearing capacity of subgrade soil for low-capacity road construction, such as village roads. In addition, the use of sawdust waste can also help reduce industrial waste in line with government efforts to increase green engineering innovations and sustainable infrastructure.

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