UNIVERSITI TEKNOLOGI MARA

PROPERTIES AND OPTIMISATION OF SLUBRITE: A SUSTAINABLE LATERITE REPLACEMENT FOR SUBGRADE APPLICATIONS

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ABSTRACT

The depletion of natural laterite and the growing volume of industrial byproducts such as Waste Paper Sludge Ash, Water Treatment Sludge, and Bottom Ash highlight the need for sustainable subgrade alternatives. This study presents SLUBRITE, a synthetic laterite replacement developed by blending these waste materials with Ordinary Portland Cement. Physicochemical and microstructural analyses confirmed the pozzolanic potential of the materials, resulting in improved strength development and long-term durability through the formation of a stable solid matrix. SLUBRITE exhibited favourable geotechnical properties, including good plasticity, compaction behaviour, and an alkaline pH range of 8.5 to 12.8, effectively neutralizing the acidity of natural laterite. Mechanical testing demonstrated superior performance, with an unconfined compressive strength of 7077 kilopascals and a California Bearing Ratio of 98.20 percent, significantly outperforming natural laterite. Response Surface Methodology optimized the mix design, identifying 20 percent Waste Paper Sludge Ash, 20 percent Water Treatment Sludge, and 60 percent Bottom Ash as the most effective blend. This composition achieved 100 percent waste substitution, satisfied subgrade performance criteria, and produced a desirability score above 0.9. The findings establish SLUBRITE as a high-performance, cost-effective, and environmentally sustainable alternative, supporting circular economy practices, reducing landfill dependency, and contributing to national waste valorisation goals.

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CHAPTER 1
INTRODUCTION

1.1 Research Background

The subgrade layer played a fundamental role in pavement construction, significantly influencing the structural integrity, load-bearing capacity, and long-term performance of road infrastructure. It served as the foundation that supported pavement layers, making its strength and durability essential for ensuring road stability and longevity (Dias Dwi Hatmoko et al., 2024; Paneru, 2020). Traditionally, laterite soil had been widely used as a subgrade material, particularly in tropical and subtropical regions, due to its abundance and cost-effectiveness (Nait-Rabah et al., 2023). However, laterite soil presented several challenges, including high variability in mechanical properties, susceptibility to moisture fluctuations, and rapid deterioration under cyclic loading, all of which contributed to pavement failures, increased maintenance costs, and reduced service life (Mbengue et al., 2022; Tang et al., 2023). Furthermore, the uncontrolled excavation of laterite soil raised significant environmental concerns, leading to issues such as deforestation, soil erosion, and depletion of natural resources (Chantruthai et al., 2017; Neupane et al., 2023). These challenges highlighted the urgent need for sustainable alternatives that could provide comparable or superior subgrade performance while reducing the ecological impact of laterite extraction.

Recent studies had explored the potential of industrial by-products as sustainable stabilizers and subgrade materials in road construction. Several waste-derived materials, including Water Treatment Sludge (WTS), Waste Paper Sludge Ash (WPSA), and Bottom Ash (BA), had been identified as promising alternatives due to their cementitious and pozzolanic properties, which could contribute to improving soil strength, durability, and moisture resistance (Chmielewska & Gosk, 2022; C. H. Liu & Hung, 2023; Mavroulidou et al., 2022). WTS, a by-product of water purification processes, contained fine particles with binding characteristics, making it a potential stabilizing agent when combined with other materials (Boscov et al., 2021). Similarly, WPSA, derived from the incineration of paper sludge, was found to contain high silica and alumina content, enhancing its pozzolanic reactivity and suitability as a partial cement replacement (Jia et al., 2021; Mavroulidou et al., 2022). Additionally, BA, a