

CHAPTER I

INTRODUCTION

1.1 Statement of the problem

The construction and maintenance of roadway pavements require substantial amounts of raw materials and energy, resulting in significant environmental impacts. Conventional pavements utilize virgin aggregates and cement, which deplete natural resources and produce greenhouse gas emissions. As a result, there is an urgent need for a sustainable pavement material option that minimizes ecological footprints.

Recent estimates indicate that upgrading roadway infrastructure worldwide requires billions of metric tons of concrete and asphalt (Alamgir et al., 2017). The extraction, processing, and transport of raw virgin materials contribute to resource depletion. Cement production alone is responsible for 5-8% of global carbon dioxide emissions (Ige, Von Kallon, & Desai, 2024). Furthermore, the disposal of old pavement material burdens landfills, exacerbating environmental concerns.

In this context, developing alternative eco-friendly pavement solutions has become a priority. The utilization of industrial by-products and recycled waste materials offers prospects for reducing the reliance on virgin resources. Recycled concrete aggregate (RCA) is acquired through the process of recycling concrete from demolished buildings, road infrastructure, and other concrete structures. The reuse and recycling of RCA in new pavement structures not only contributes to reducing waste in landfills but also conserves natural resources by reducing the need for virgin aggregate materials. However, RCA has some limitations in mechanical performance, necessitating the development of effective geochemical stabilization methods.

The adoption of natural rubber latex (NRL) to modify cement-stabilized RCA has been found to be an innovative approach to enhance the performance and sustainability of pavement base materials (Hoy, Nhieu, et al., 2023; Hoy, Vinh Nhieu, et al., 2023; Nhieu et al., 2023). NRL is a milky white liquid extracted from the bark of the rubber tree (*Hevea brasiliensis*). It is a natural polymer consisting of rubber particles suspended in an aqueous medium. The composition of NRL includes water (50-70%), rubber particles (30-40%), and small amounts of proteins, lipids, and other substances (Bottier, 2020).

The innovation of using NRL-modified cement stabilization of RCA lies in its ability to address some of the limitations of conventional cement-stabilized RCA, such as brittle manner and low tensile ability. By incorporating NRL into the cement-RCA mixture, the resulting material exhibits improved engineering performance such as higher compressive and tensile strengths, strain capacity, and toughness.

Similar studies (Hoy, Tran, Suddeepong, Horpibulsuk, Buritatum, et al., 2023; Hoy, Tran, Suddeepong, Horpibulsuk, Mobkrathok, et al., 2023; Tran et al., 2022) initiated the innovative utilization of NRL to enhance mechanical properties and service life of cement-stabilized recycled materials, particularly RCA and steel slag blended with lateritic soil. It represents a significant advancement in sustainable pavement engineering. This eco-friendly approach combines the benefits of using recycled materials with the unique properties of NRL to create high-performing, resilient, and durable pavement base layers that can withstand the detrimental effects of wetting and drying cycles. The optimization of NRL content in cement-stabilized recycled materials from demolition wastes is crucial to achieving the desired performance improvements. The optimal NRL-to-cement ratios maximize the beneficial effects of NRL while avoiding excessive amounts that can hinder cement hydration and strength development.

Geopolymer technology represents a revolutionary approach in the field of construction materials, offering a sustainable alternative to traditional cement. Geopolymers are formed by the chemical reaction of aluminosilicate materials, such as fly ash or slag, with alkaline solutions. This reaction produces a dense, three-dimensional network structure that provides excellent mechanical strength, durability, and resistance to chemical attack. The environmental benefits of geopolymer technology are significant, as it utilizes industrial by-products and reduces CO₂ emissions associated with cement production. Several studies have reported on the success of geopolymer-stabilized recycled materials in pavement applications (Mohammadinia et al., 2016; Xie et al., 2024; Zhang et al., 2021).

The widespread adoption of fly ash in Portland cement concrete has led to extensive research on fly ash-based geopolymers, resulting in a comprehensive body of literature (Amran, Debbarma, & Ozbakkaloglu, 2021; Klima, Schollbach, Brouwers, & Yu, 2022; Li et al., 2022; Rathnayaka et al., 2024). However, it was reported that bottom ash (BA)-based geopolymers may exhibit poorer mechanical properties and durability than fly ash-based geopolymers owing to the lower reactivity and coarser particle size of BA (Chindaprasirt, Jaturapitakkul, Chalee, & Rattanasak, 2009; ul Haq, Padmanabhan,

& Licciulli, 2014). These performance concerns have hindered the adoption of bottom ash in geopolymer production.

Within the context of sustainable material innovation, the integration of NRL-modified BA in geopolymer stabilization of RCA opens new avenues for high-performance base materials. The inclusion of NRL in the bottom ash geopolymer matrix introduces unique properties to the pavement base material. NRL, known for its elasticity and water resistance, imparts flexibility and resilience to the geopolymer-stabilized RCA. This modification is particularly beneficial for pavement applications, where pavement materials are subjected to dynamic loads and environmental stresses. The NRL not only helps absorb and distribute these loads more effectively, reducing the risk of cracking, but also provides a barrier against moisture infiltration, enhancing the durability of the pavement base.

The current research attempts to explore the strength development of NRL-modified BA based geopolymer stabilized RCA as a greener material in pavement applications. Geopolymer is formed through the reaction of an aluminosilicate source, such as bottom ash (precursor), with an alkaline activator solution containing sodium hydroxide (NaOH) and sodium silicate (Na_2SiO_3). The alkaline activator solutions were prepared with various Na_2SiO_3 :NaOH (G/N) ratios of 1:1, 1:1.5, and 1:2, while the mixtures were modified with NRL at contents of 0.1, 0.2, and 0.3 by weight of the aggregate. The unconfined compressive strength (UCS) test was carried out to determine the strength of the studied mixtures at 7 and 28 days of curing. The strength development was examined through the microstructural and mineralogical analyses using scanning electron microscopy (SEM), energy dispersive x-ray spectroscopy (EDS) and x-ray diffraction (XRD), respectively.

As the outcomes of this study, linking NRL-modification with the stabilization of RCA with bottom ash geopolymer technology represents a newly frontier in pavement engineering. This collaboration could lead to the development of advanced pavement materials that meet the dual demands of sustainability and performance, catering to the infrastructure needs of the future while adhering to the principles of green construction.

1.2 Objectives of the study

This research has been undertaken with the following objectives:

1.2.1 Investigate the strength development of NRL-modified bottom ash based geopolymer stabilized RCA as a sustainable pavement material.

1.2.2 To study the effect of NRL-modification with the stabilization of RCA with bottom ash geopolymer.

1.3 Organization of the Dissertation

This thesis consists of five chapters and the outlines of each chapter are presented as follows:

Chapter I presents the introduction part, describing the statement of the problems, the objectives of the study, and the organization of the dissertation.

Chapter II presents a literature review related to recycled concrete aggregate, Bottom coal ash, Geopolymer and natural rubber latex. Applications in road construction projects in the past, present, and future trends.

Chapter III presented the study testing procedure, sample preparation, standard of testing, mixed ingredients, and results of unconfined compressive strength with strength development of bottom ash geopolymer stabilized recycled concrete aggregate with various RCA – BA ratio 90:10,80:20,70:30,60:40,50:50 is a factor studied in this research included liquid alkaline activator (L) content, Na_2SiO_3 /NaOH (G/N) is (1/1), (1/1.5), (1/2.0) and curing at room temperature (RT) condition, test UCS at 7 – 28 days. This study has significant impacts on base/subbase layer application for the road construction authority of Thailand by using RCA stabilized with BA geopolymer binder, a sustainable alternative to ordinary PC, in pavement base and subbase course material.

Chapter IV presented the study testing procedure, sample preparation, standard of testing, mixed ingredients, and results of unconfined compressive strength with various Na_2SiO_3 :NaOH (G/N) ratios of 1:1, 1:1.5, and 1:2, while the mixtures were modified with NRL at contents of 0.1, 0.2, and 0.3 by weight of the aggregate. After that, the sample was examined with the SEM and Energy Dispersive X-Ray Spectroscopy EDS to analyze the effect of NRL modification with the stabilization of RCA with bottom ash geopolymer. In progress and follow up.

Chapter V presents the conclusion of each chapter and the overall conclusion. The suggestion for further study is also shown in this chapter.

1.4 Reference

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