INVESTIGATION OF THE PROPERTIES OF CARBON BLACK MODIFIED BITUMEN AND HOT MIX ASPHALT MIXTURES

H.M.S.D. Jayasinghe

238038R

Degree of Master of Science

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Thesis submitted in partial fulfillment of the requirements for the degree

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DECLARATION

I declare that this is my own work and this thesis/dissertation does not incorporate without acknowledgement any material previously submitted for a degree or diploma in any other University or Institute of higher learning and to the best of my knowledge and belief it does not contain any material previously published or written by another person except where the acknowledgement is made in the text. I retain the right to use this content in whole or part in future works (such as articles or books).

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The above candidate has carried out research for the Masters thesis under my supervision. I confirm that the declaration made above by the student is true and correct.

Name of Supervisor: Dr. Chamod Hettiarachchi

Signature of the Supervisor: Date:28/05/2025

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Sudharshi Jayasinghe

ABSTRACT

The traffic volume, tyre pressure, and environmental conditions cause the depletion of road pavement performance levels. However, to enhance road quality, improving pavement performance is vital. Researchers have been studying ways to improve the performance of pavements by modifying the asphalt using various materials. With the emerging trend towards low carbon emission materials, waste-based materials are usually investigated on their ability to modify conventional construction materials. Pyrolysis Carbon Black (PCB) is a by-product of the waste tyre recycling process, which can potentially improve pavement performance. This study aims to investigate the properties of PCB modified bitumen and its performance impact factors. Further to evaluate the manufacturing process of PCB-modified asphalt concrete by comparing the effects of wet and dry mixing methods on pavement performance when PCB is incorporated with asphalt. Penetration, softening point and Dynamic Shear Rheometer (DSR) test was conducted to investigate the Rheological and Physical properties. Marshall Stability and flow tests are used to evaluate the volumetric properties. The bitumen properties provide the evidence of ability to improve the rutting resistance and high temperature performance of the asphalt by adding PCB. Further volumetric properties show that both methods have improved the asphalt properties where the flow has increased in wet and dry mixing mixtures, compared to the conventional mixture. Moreover, PCB modified road section was evaluated and calculated Pavement Condition Index (PCI). For better insight, another section from the same road prepared with conventional asphalt at the same period was evaluated. The calculated PCI values are 85% and 88% for conventional and PCB-modified pavements, respectively demonstrating the potential for long-term performance in PCB-modified pavements. PCB can be recommended as a promising modifier option to develop pavement performance while adhering to sustainability guidelines. Furthermore, additional investigations into low-temperature performance and wet mixing manufacturing process of PCB-modified asphalt are encouraged.

Keywords: Pyrolysis Carbon Black (PCB), Bitumen modification, Asphalt concrete, wet mixing, dry mixing, Pavement Condition Rating

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF ABBREVIATIONS

Abbreviation	Description
AHO	Aromatic hydrocarbon oil
BET	Brunauer-Emmett-Teller
BR	Butyl Rubber
CB	Carbon black
CCB	Commercial carbon black
CDV	Corrected Deduct Value
CEB	Ceylon Electricity Board
CPCB	Co-pyrolytic carbon black
DBP	Dibutyl phthalate
DSR	Dynamic Shear Rheometer
DV	Deduct Value
EDS	Energy-dispersive X-ray spectroscopy
EE	Embodied energy
$ECO_{2\text{-}e}$	Embodied GHG Emissions
FTIR	Fourier transform infrared spectroscopy
GHG	Greenhouse gas
HMA	Hot mix asphalt
HSE	Health and Safety Executive
NPCB	Nano-carbon black
OBC	Optimum Bitumen Content
OSHA	Occupational Safety and Health Administration
PAH	Polynuclear aromatic hydrocarbons
PAV	Pressure Age Vessel

PCB	Pyrolysis Carbon Black
PCI	Pavement Condition Index
PE	Polyethylene
PET	Polyethylene Terephthalate
PI	Penetration Index
RPM	Rounds Per Minutes
RTFO	Rolling Thin Film Oven
SBS	Styrene butadiene styrene
SBR	Styrene-butadiene copolymer
SEM	Scanning electron micrograph
SFE	Surface free energy
SSCM 05	Standard Specification for Construction and Maintenance of Roads and Bridges
TDV	Total deducts value
UV	Ultra-violet
VMA	Voids in Mineral Aggregate
VPCB	Vacuum pyrolysis carbon black
XRD	X-ray diffraction

LIST OF APPENDICES