

## INVESTIGATION OF ACTIVATED CARBON-MODIFIED BITUMEN USING COCONUT CHARCOAL

V.J.S. Wickramasinghe <sup>1</sup>, H.A.C.K. Hettiarachchi <sup>1, \*</sup>, W.K. Mampearachchi <sup>2</sup>

<sup>1</sup> Department of Civil Engineering, University of Moratuwa, Moratuwa

<sup>2</sup> Research Scientist/ UF Consultant – Florida, Department of Transportation, Engineering School of Sustainable Infrastructure & Environment

The growing demand for sustainable and resilient road infrastructure in tropical regions has intensified the search for innovative materials that enhance pavement performance while minimising environmental impact. Conventional bitumen, widely used as a binder in flexible pavements, is prone to thermal softening, oxidative aging, and rutting issues made worse by high ambient temperatures and heavy traffic typical of tropical climates. This research investigates the potential of activated carbon (AC) derived from coconut shells, an abundant agricultural by-product, as a sustainable modifier for 60/70 penetration grade bitumen. The study aims to address key challenges in pavement durability and sustainability by systematically exploring how varying AC content, mixing temperature, and mixing rate affect the physical, rheological, and thermal properties of bitumen.

A full factorial experimental design was employed, varying three independent parameters: AC content (3%, 6%, 9% by weight), mixing temperature (140°C, 150°C, 160°C), and mixing rate (2000 rpm, 3000 rpm, 4000 rpm). This included 27 modified bitumen samples, and a control sample. Standard physical tests including penetration, softening point, and ductility were conducted on all samples. The optimum formulation, identified as 3% AC at 140°C and 3000 rpm, was further subjected to advanced characterisation, including dynamic viscosity test, Thin Film Oven (TFO) aging, optical microscopy, and Fourier-transform infrared (FTIR) spectroscopy.

The incorporation of coconut shell-derived AC resulted in a significant reduction in penetration values, indicating increased binder stiffness and hardness. The optimum sample exhibited a 34.9% decrease in penetration compared to the base bitumen, while all modified samples demonstrated elevated softening points (up to 56°C), reflecting enhanced resistance to high temperatures. Importantly, ductility values for all modified binders remained above the AASHTO minimum requirement, confirming that flexibility was not compromised. Viscosity measurements revealed that the optimum AC-modified binder had a reduced viscosity (241.5 cP versus 362.5 cP for the base), which improves workability and allows for lower processing temperatures, contributing to energy savings and reduced emissions. Despite the reduction of viscosity, the modified binder maintained superior hardness and thermal stability, mitigating potential rutting risks.

Aging resistance, evaluated through TFO testing, showed that the AC-modified sample experienced lower mass loss (0.55% vs. 0.71%) and a smaller increase in softening point post-aging, indicating improved durability and reduced susceptibility to oxidative degradation. Optical microscopy confirmed uniform dispersion of AC particles within the bitumen matrix, contributing to the observed enhancements in mechanical and thermal properties.

**Keywords:** Aging resistance, Coconut charcoal, Rheology, Sustainable materials, Thermal stability, Viscosity

\* Correspondence: [chamodh@uom.lk](mailto:chamodh@uom.lk)

INVESTIGATION OF ACTIVATED CARBON-MODIFIED BITUMEN USING COCONUT CHARCOAL



+



Mixing using laboratory shear mixer

| Samples  |          |          |          |          |          |          |          |          |
|----------|----------|----------|----------|----------|----------|----------|----------|----------|
| 0%       |          |          | 3%       |          |          | 6%       |          |          |
| 140 °C   |          |          | 150 °C   |          |          | 160 °C   |          |          |
| 2000 rpm | 2000 rpm | 2000 rpm | 2000 rpm | 2000 rpm | 2000 rpm | 2000 rpm | 2000 rpm | 2000 rpm |
| 3000 rpm | 3000 rpm | 3000 rpm | 3000 rpm | 3000 rpm | 3000 rpm | 3000 rpm | 3000 rpm | 3000 rpm |
| 4000 rpm | 4000 rpm | 4000 rpm | 4000 rpm | 4000 rpm | 4000 rpm | 4000 rpm | 4000 rpm | 4000 rpm |

3-Percentage variations

3-Temperature variations

3-Mixing rate variations

TESTINGS



Penetration test



Softening Point test



Ductility test



Viscosity test



TFO test

OPTIMAL SAMPLE

3% AC Content

140 °C Temperature

3000 rpm Rate

KEY FINDINGS

ENHANCED PROPERTIES

- Penetration reduced by 34% (63 to 41 dmm)
- Softening point improved from 50 °C to 54 °C

SUSTAINABILITY BENEFITS

- Coconut shell waste valorization
- Eco-friendly alternative to polymer
- Enhanced heat resistance for tropical climates

FUTURE APPLICATIONS

- Recommended for high-traffic roads in tropical regions
- Performance validation through field trials
- Potential for hybrid modifiers with polymers