

## Utilization of Pyrolysis Carbon Black in Bitumen Modification

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### Abstract

The constant demand for improved pavement performance and sustainability has influenced researches into alternative materials for bitumen modification. Pyrolysis Carbon Black (PCB), derived from waste tire pyrolysis, represents an environmentally friendly and economically viable additive for enhancing bitumen properties. Utilizing PCB not only offers a promising solution to tire waste management but also has the potential to improve the physical and rheological behaviour of bituminous binders used in road construction. This study investigates the influence of PCB particle size and mixing speed on the physical and chemical characteristics of PCB-modified bitumen. Bitumen samples were prepared with a fixed percentage of PCB, while varying key modification parameters such as particle size and shear mixing speed. The objective is to understand how these parameters impact binder properties and to provide a foundation for optimizing PCB-modified bitumen formulations. Physical properties including penetration and softening point were measured to evaluate the consistency, stiffness, and temperature susceptibility of the binders. Penetration tests provide a measure of binder hardness, which relates directly to performance characteristics like flexibility and deformation resistance. The softening point test complements this by indicating the temperature at which the binder transitions from a solid to a semi-fluid state, informing on temperature susceptibility and high-temperature performance. To investigate chemical interactions between PCB and bitumen, Fourier Transform Infrared Spectroscopy (FTIR) analysis was performed. This technique identifies functional groups and molecular structures, helping to reveal whether chemical bonding or significant molecular changes occur during modification. Understanding these interactions is crucial for interpreting how PCB affects binder performance and durability. The study further explores the effects of aging on PCB-modified binders, an important consideration since bitumen in pavements undergoes oxidative aging during service life. Long-term aging simulations were conducted using a Pressure Aging Vessel (PAV), which accelerates oxidative hardening under controlled temperature and pressure conditions. Penetration and softening point tests were repeated after aging to assess changes in physical properties, thereby evaluating the aging resistance imparted by PCB modification. The results provide insights into the relationship between PCB particle size and mixing speed on the modification effectiveness. Different particle sizes affect the specific surface area and dispersion of PCB within the bitumen, which in turn influences the binder's physical properties. Mixing speed, representing the shear energy input during modification, affects the uniformity and integration of PCB particles in the binder. The results showed that using finer PCB particles led to a 33% decrease in penetration value—from 60 to 40 (0.1 mm)—indicating enhanced stiffness, while softening point changed only slightly. Investigating these factors helps in optimizing processing parameters to achieve the desired binder characteristics. The aging assessment highlights how PCB modification impacts the durability and long-term behaviour of binders. This aspect is vital for ensuring that the modified bitumen maintains desirable performance under the environmental and loading conditions

experienced by pavements over time. In summary, this research contributes to the growing body of knowledge on sustainable bitumen modification using waste-derived materials. By examining the effects of particle size, mixing speed, and aging on PCB-modified bitumen, the study lays the groundwork for developing optimized designs that balance performance improvement with environmental benefits. The findings support the potential of PCB as a cost-effective and eco-friendly modifier for enhancing pavement binder properties, encouraging further research and industrial application in asphalt technology.

**Keywords:** *bitumen modification, Pyrolysis Carbon Black (PCB), particle size, mixing speed, ageing resistance, FTIR analysis*

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