Asphalt Concrete Mix Design Incorporating Natural Rubber Latex Substitution for Flexible Pavement Performance Based on the Marshall Method

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ABSTRACT

The escalating volume of traffic and heavy axle overloads trigger premature distress, predominantly in the form of permanent deformation and structural cracking within the Asphalt Concrete – Wearing Course (AC-WC) surface layer. Modifying Pen 60/70 bitumen using natural elastomers, specifically natural rubber latex, serves as a strategic alternative to enhance the rheological performance of the binder while capitalizing on local natural rubber potential from Bengkalis. This research aims to analyze homogeneous mixing procedures, evaluate the impact of natural rubber latex substitution levels on Marshall volumetric and mechanical properties, determine the optimum bitumen and rubber content, and verify the mixture performance compliance against the 2025 Bina Marga General Specifications. Wet-process blending was executed at 150˚C–160˚C utilizing mechanical agitation to prevent phase separation. Evaluation of the conventional mixture yielded an Optimum Bitumen Content (OBC) of 5.25%. Natural rubber latex was then substituted within this bitumen proportion, with the optimal performance achieved at a 4.5% substitution rate. Comparative testing at OBC conditions demonstrated an 8.18% increase in bulk density 2.20 g/cm^3 to 2.38 g/cm^3, a reduction in voids in mineral aggregate (VMA) from 16.88% to 15.37%, and a 21.86% decrease in voids in total mix (VIM) from 4.94% to 3.86%. Regarding mechanical criteria, although Marshall stability decreased by 10.63% (from 1076.69 kg to 962.25 kg), it remained well above the minimum specification limit. Plastic flow was controlled at 2.60 mm, and the Marshall Quotient (MQ) increased by 2.42% (from 379.22 kg/mm to388.42 kg/mm). The concurrent increase in Marshall Quotient and density confirms that natural rubber latex substitution successfully enhances the mixture's stiffness and resistance to permanent deformation without compromising pavement flexibility. All evaluated parameters fully satisfy the 2025 Bina Marga Technical Specifications, establishing local natural rubber latex as a viable, durable, and environmentally sustainable pavement modifier.

Keywords: Flexible Pavement, Natural Rubber Latex, Wet Process, Marshall Test, Marshall Characteristics.