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Pengaruh Aspal Modifikasi Bio-Oil Tandan Kosong Kelapa Sawit (Tkks) Pada Ketahanan Terhadap Deformasi Permanen (Rutting) Campuran AC-WC
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INTISARI

Kerusakan jalan berupa deformasi permanen (*rutting*) dan keretakan akibat kombinasi beban lalu lintas berulang serta kelembapan (*moisture damage*) merupakan tantangan utama pada lapisan *Asphalt Concrete – Wearing Course* (AC-WC) di kawasan beriklim tropis. Salah satu pendekatan yang berkembang untuk meningkatkan performa campuran beraspal sekaligus mendukung pemanfaatan limbah biomassa adalah penggunaan *bio-oil* berbasis tandan kosong kelapa sawit (TKKS) sebagai bahan modifikasi aspal. Meskipun berbagai penelitian telah melaporkan potensi *bio-oil* dalam meningkatkan karakteristik aspal, kajian yang mengintegrasikan evaluasi durabilitas, ketahanan terhadap deformasi permanen, dan ketahanan terhadap kerusakan akibat kelembapan pada campuran AC-WC masih relatif terbatas. Penelitian ini bertujuan untuk menentukan Kadar Aspal Optimum (KAO), menganalisis pengaruh *bio-oil* TKKS terhadap durabilitas, ketahanan terhadap deformasi permanen, ketahanan terhadap moisture damage, serta menentukan kadar bio-oil optimum pada campuran AC-WC.

Penelitian dilakukan secara eksperimental di laboratorium menggunakan aspal penetrasi 60/70 yang dimodifikasi dengan *bio-oil* TKKS pada variasi kadar 0%, 5%, 10%, dan 15% terhadap berat aspal. Pengujian meliputi karakteristik aspal, Marshall, *Marshall Immersion*, *Retained Marshall Stability* (RMS), *Wheel Tracking Machine* (WTM), *Indirect Tensile Strength* (ITS), dan *Tensile Strength Ratio* (TSR). Analisis data dilakukan secara deskriptif-komparatif berdasarkan spesifikasi Bina Marga 2018 Revisi 2 dan AASHTO T283.

Hasil penelitian menunjukkan bahwa nilai KAO untuk variasi *bio-oil* TKKS 0%, 5%, 10%, dan 15% berturut-turut sebesar 5,6%; 6,3%; 6,0%; dan 5,8%. Variasi *bio-oil* TKKS 5% menghasilkan nilai RMS dan TSR tertinggi masing-masing sebesar 93,21% dan 87,63%, yang menunjukkan durabilitas dan ketahanan terhadap *moisture damage* terbaik. Sementara itu, variasi 10% menghasilkan kinerja terbaik terhadap deformasi permanen berdasarkan hasil WTM serta menunjukkan nilai *Marshall Stability* dan ITS yang lebih tinggi dibanding variasi lainnya. Berdasarkan evaluasi menyeluruh terhadap seluruh parameter penelitian, kadar *bio-oil* TKKS sebesar 10% ditetapkan sebagai kadar optimum karena memberikan keseimbangan terbaik antara *durabilitas*, ketahanan terhadap deformasi permanen, dan ketahanan terhadap kerusakan akibat kelembapan pada campuran AC-WC.

Kata Kunci: AC-WC, *Bio-oil* TKKS, *Durabilitas*, *Moisture Damage*, *Rutting*.

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ABSTRACT

Pavement distresses in the form of permanent deformation (rutting) and cracking, induced by the combined action of repeated traffic loading and moisture damage, represent major challenges for Asphalt Concrete – Wearing Course (AC-WC) layers in tropical regions. One promising approach to enhance asphalt mixture performance while promoting sustainable utilization of agricultural waste is the incorporation of bio-oil derived from Oil Palm Empty Fruit Bunches (OPEFB) as an asphalt modifier. Although previous studies have reported the potential of bio-oil to improve asphalt properties, comprehensive investigations integrating durability, rutting resistance, and moisture damage performance in AC-WC mixtures remain limited. Therefore, this study aimed to determine the Optimum Asphalt Content (OAC), evaluate the effects of OPEFB bio-oil on durability, permanent deformation resistance, and moisture damage resistance, and identify the optimum bio-oil content for AC-WC mixtures.

An experimental laboratory study was conducted using Pen 60/70 asphalt modified with OPEFB bio-oil at contents of 0%, 5%, 10%, and 15% by weight of asphalt binder. The testing program included asphalt binder characterization, Marshall testing, Marshall Immersion, Retained Marshall Stability (RMS), Wheel Tracking Machine (WTM), Indirect Tensile Strength (ITS), and Tensile Strength Ratio (TSR). Data were analyzed using a descriptive-comparative approach based on the requirements of the Indonesian Bina Marga 2018 Revision 2 specifications and AASHTO T283.

The results indicated that the OAC values for bio-oil contents of 0%, 5%, 10%, and 15% were 5.6%, 6.3%, 6.0%, and 5.8%, respectively. The 5% bio-oil mixture exhibited the highest RMS and TSR values of 93.21% and 87.63%, respectively, indicating superior durability and moisture damage resistance. Meanwhile, the 10% bio-oil mixture demonstrated the best rutting resistance based on WTM performance and achieved higher Marshall Stability and ITS values compared to the other mixtures. Based on the integrated evaluation of all performance parameters, the optimum OPEFB bio-oil content was determined to be 10%, as it provided the most balanced performance in terms of durability, permanent deformation resistance, and moisture damage resistance for AC-WC mixtures.

Keywords: AC-WC, OPEFB Bio-oil, Durability, Moisture Damage, Rutting.