BINDER CHARACTERIZATION AND PERFORMANCE OF WARM STONE MASTIC ASPHALT MIXTURE

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"I dedicated this thesis to my late father, Amb. Suleiman Yero and late mother, Hajia Fatima Babagana, and to my be loved family for their awesome support and patience"

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ABSTRACT

The conventional stone mastic asphalt (SMA) is normally produced at high temperature (180^{o}C) that consumes fuel, increases cost, and generates heat with emissions of green house gases. This study investigated the potential of producing stone mastic asphalt at lower temperature (130^{o}C) termed as warm stone mastic asphalt (WSMA) against the normal high mixing temperature. Three grades of bitumen 80/100, 60/70 and PG 76-22 were investigated. A long chain aliphatic hydrocarbon Sasobit wax (SW) was used as an additive to reduce the mixing temperature. The Sasobit wax was incorporated at 0.5%, 1%, 1.5%, 2%, 2.5% and 3% of bitumen content. The empirical tests were conducted on 105 samples of the three binder types, which include penetration test at 10^{o}C and 25^{o}C. Softening point test, dynamic viscosity (DV) at 135^{o}C and kinematic viscosity (KV) at 60^{o}C were conducted to determine the penetration index (PI) and penetration viscosity number (PVN). The results indicate the modified bitumen has better resistance to temperature susceptibility with the additive and better resistance to rutting as it decreases the viscosity of the binder at high temperatures and produces high stiffness modulus as compared to the base bitumen. The study also investigated 126 samples for rheology test of the bitumen using the rolling thin film oven test (RTFOT), pressure aging vessel (PAV), and dynamic shear rheometer (DSR). The results from these tests at high test temperature indicate higher complex shear modulus (G*/sinδ) with low phase angle (increase stiffness) for aged modified binders indicating better resistance to rutting damage, while at low test temperature they exhibit low complex modulus with high phase angle (decrease stiffness) indicating better resistance to fatigue. The testing on the compatibility and morphology of the modified binders using the scanning electron microscopy test (SEM) were also conducted. The results show the homogeneity of the binder with Sasobit as is completely soluble in the binder with no agglomeration. The study investigated the effect of the warm asphalt additive on the binder aging using Fourier transformation infrared test (FTIR). The results show an insignificant impact on the binder aging. The study prepared and investigated 225 samples of SMA14 and WSMA14 mixtures using the Marshall mix design. The flow and stability tests conducted on the WSMA mixtures show values higher than the minimum JKR/SPJ/2008-S4 specification for SMA in Malaysia with less than 2.5% Sasobit in the three binder sourced investigated. The study recommends up to 2% Sasobit for PEN 80/100, up to 1.5% for PEN 60/70 and 1% for PG 76-22. Based on the penetration test conducted, the two modified PEN bitumen can be categorized as PG 76-22. Also the performance test on the asphalt mix with Sasobit that include rutting and resilient modulus test indicated resistance to rutting damage. Thus, it can be concluded that the Sasobit wax improves bitumen performance, decreases asphalt production temperatures and is feasible to be used in the production of WSMA.

ABSTRAK

Stone mastic asphalt (SMA) konvensional dihasilkan pada suhu campuran yang tinggi iaitu 180^{o}C. Ini akan mengakibatkan peningkatan penggunaan bahan api, penghasilan haba dan pelepasan gas rumah hijau. Kajian ini dijalankan untuk mengkaji potensi penghasilan stone mastic asphalt pada suhu campuran yang lebih rendah berbanding suhu campuran normal iaitu 130^{o}C. Campuran ini dinamakan warm stone mastic asphalt (WSMA). Tiga gred bitumen digunakan dalam kajian ini iaitu gred 80/100, 60/70 dan PG 76-22. Rantaian panjang alifatik hidrokarbon lilin Sasobit wax (SW) digunakan sebagai bahan tambah untuk mengurangkan suhu campuran. Lilin Sasobit dicampukan pada kadar 0.5%, 1%, 1.5%, 2%, 2.5% dan 3% daripada kandungan bitumen. Ujian-ujian empirical telah dijalankan ke atas 105 sampel yang mewakili ketiga-tiga jenis bitumen tersebut. Ujian-ujian yang dijalankan adalah ujian penusukan pada suhu 10^{o}C dan 25^{o}C, ujian titik lembut, ujian kelikatan dinamik (DV) pada suhu 135 ^{o}C dan kelikatan kinematik (KV) pada suhu 60 ^{o}C yang bertujuan untuk mementukan indeks penusukan (PI) dan nombor kelikatan penusukan (PVN). Keputusan menunjukkan bitumen yang diubahsuai dengan bahan tambah mempunyai rintangan yang lebih baik terhadap suhu dan perpalohan. Ini disebabkan bahan tambah tesebut dapat mengurangkan kelikatan pengikat pada suhu tinggi dan menghasilkan modulus kekerasan yang tinggi berbanding bitumen asas. Ujian-ujian reologi turut dijalankan ke atas 126 sampel bitumen yang melibatkan ujian Rolling Thin Film Oven (RTFOT), Pressure Aging Vessel (PAV), dan Dynamic Shear Rheometer (DSR). Keputusan ujian bagi pengikat tua (aged binder) pada suhu tinggi menunjukkan modulus ricih kompleks (G*/sinδ) yang tinggi dengan sudut fasa yang rendah (kekerasan meningkat). Ini menunjukkan rintangan yang lebih baik terhadap perpalohan. Manakala, ujian pada suhu rendah mencatatkan modulus ricih kompleks yang rendah dengan sudut fasa yang tinggi (kekerasan menurun). Ini menunjukkan rintangan yang lebih baik terhadap kelesuan (fatigue). Ujian kesesuaian dan morfologi ke atas pengikat diubahsuai turut dijalankan dengan menggunakan ujian pengimbasan mikroskopi electron (SEM). Keputusan ujian menunjukkan keseragaman pengikat dan Sasobit di mana Sasobit larut di dalam pengikat tanpa ada penggumpalan. Selain itu, kajian kesan penuaan pengikat terhadap bahan tambah asfal sederhana panas (warm asphalt) dengan menggunakan ujian transformasi inframerah fourier (FTIR). Keputusan ujian menunjukkan kesan yang tidak ketara pada penuaan pengikat. Kajian terhadap 225 sampel SMA14 dan WSMA14 menggunakan rekabentuk Marshall turut dijalan. Keputusan ujian aliran dan kestabilan menunjukkan campuran WSMA diubahsuai bagi ketiga-tiga jenis bitumen dengan 2.5% Sasobit masing-masing mematuhi spesifikasi JKR/SPJ/2008-S4. Kajian ini mencadangkan 2% Sasobit untuk bitumen 80/100 PEN, 1.5% untuk bitumen 60/70 PEN dan 1% untuk bitumen PG 76-22. Ujian prestasi terhadap perpalohan dan resilient modulus bagi campuran diubahsuai ini menunjukkan campuran ini mematuhi spesifikasi yang telah ditetapkan. Kesimpulan dari kajian ini membuktikan lilin Sasobit dapat meningkatkan prestasi bitumen, mengurangkan suhu campuran asphalt dan boleh dipraktikkan dalam penghasilan WSMA.