ASPHALT BINDER AND MIXTURE PERFORMANCE USING BATU PAHAT SOFT CLAY AS MODIFIER

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DEDICATION

I would like to announce my appreciation to Allah Almighty for his grace, guidance and protection of me during my Ph.D. study. I dedicate this dissertation with countless appreciation to my beloved parents, and to all my beloved family members who had supporting me throughout my study life.

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ABSTRACT

Road construction is required to provide better mobility for the community. This research aims to evaluate the use of BPSC particles as additive in Hot Mix Asphalt (HMA) mixture which was previously introduced in powder form. The experimental work for this survey included the use of four BPSC ratios (2, 4, 6 and 8%) according to the weight of bitumen. A design for the hot mix asphalt was executed by using the Superpave method for each additive ratio. However, using soft clay as filler to modify asphalt binder and mixture was not intensively done by researchers. Additionally, physical properties results of penetration and softening point show that soft clay can increase the binder stiffness, while storage stability of modified asphalt binder had a good compatibility between the original and modified binder. The rheological properties results such as dynamic shear rheometer indicated that soft clay modified asphalt binder would increase the stiffness and the elastic behavior compared to unmodified binder at intermediate and high temperatures. It has also the lowest susceptibility for rutting and the temperature susceptibility. In addition, microstructure examinations of the asphalt binders were then achieved by using scanning electron microscopy, hence; images displayed that soft clay particles distributed uniformly in the asphalt matrix. In addition, asphalt mixture test such as indirect resilient modulus, indicated that the stiffness increased as the percentages of soft clay increased. Also, dynamic creep results showed that the adding soft clay to asphalt mixtures remarkably decreases its susceptibility to permanent deformation. As for the moisture susceptibility, all the samples pass the 80% tensile strength ratio, it could be noted that BPSC had improved adhesion strength between an aggregate and binder. Furthermore, ageing index values show that the susceptibility to oxidative ageing was significantly reduced with the increase of BPSC content after short-term aging, and also it was observed that short-term aging had given a good resistance to oxidation. Studies on correlation analysis between different rheological modified asphalt binder and mixture of HMA were also conducted. It was shown that a strong correlation exists among $G^*/\sin \delta$ and rut depth. In conclusion, the introduction of BPSC has a bright potential as a new material of HMA which can be used in pavement construction in the future.

ABSTRAK

Pembinaan jalan diperlukan untuk memberi mobiliti yang lebih baik kepada masyarakat. Kajian ini bertujuan untuk menilai penggunaan BPSC sebagai bahan tambahan dalam Campuran Asfalt Panas (HMA) yang sebelum ini diperkenalkan dalam bentuk serbuk. Kerja eksperimen untuk kajian ini menggunakan empat nisbah BPSC (2, 4, 6 dan 8%) mengikut berat bitumen. Reka bentuk untuk asfalt campuran panas telah dilaksanakan dengan menggunakan kaedah Superpave bagi setiap nisbah bahan tambahan. Bagaimanapun, penggunaan tanah liat lembut sebagai pengisi untuk mengubah pengikat asfalt dan campuran tidak dilakukan secara intensif oleh penyelidik. Selain itu, sifat-sifat fizikal penusukan dan titik pelembut menunjukkan bahawa tanah liat lembut dapat meningkatkan ketegangan pengikat, sementara kestabilan penyimpanan pengikat asfalt diubahsuai mempunyai keserasian yang baik antara pengikat asal dan diubahsuai. Keputusan sifat-sifat reologi seperti reometer ricih dinamik menunjukkan bahawa pengikat asfalt diubahsuai dengan tanah liat lembut akan meningkatkan ketegangan dan kelakuan elastik berbanding dengan pengikat yang tidak diubahsuai pada suhu pertengahan dan tinggi. Ia juga mempunyai kerentanan yang paling rendah untuk aluran dan suhu. Di samping itu, pemeriksaan mikrostruktur pengikat asfalt telah dicapai dengan menggunakan mikroskop elektron imbasan, dimana; Imej yang dipaparkan menunjukkan bahawa zarah-zarah tanah liat lembut diagihkankan secara seragam dalam matriks asfalt. Di samping itu, ujian campuran asfalt seperti modulus berdaya tahan tidak langsung, menunjukkan bahawa ketegangan meningkat apabila peratusan tanah liat lembut meningkat. Hasil penyelidikan rayapan dinamik juga menunjukkan bahawa

penambahan tanah liat lembut dalam campuran asphalt mengurangkan kerentanannya terhadap perubahan bentuk kekal. Bagi kerentanan kelembapan, semua sampel melepasi nisbah kekuatan tegangan 80%, ini menunjukkan bahawa BPSC telah meningkatkan kekuatan lekatan antara agregat dan pengikat. Tambahan pula, nilai indeks penuaan menunjukkan bahawa kerentanan terhadap penuaan oksidatif berkurangan dengan peningkatan kandungan BPSC selepas penuaan jangka pendek. Ia juga diperhatikan bahawa penuaan jangka pendek telah memberikan ketahanan yang baik terhadap pengoksidaan. Kajian mengenai analisis korelasi antara pengikat asfalt diubahsuai dan campuran HMA juga telah dijalankan. Didapati bahawa korelasi yang kuat wujud di antara $G^*/\sin\delta$ dan kedalaman aluran. Kesimpulannya, pengenalan BPSC mempunyai potensi yang cerah sebagai bahan baru HMA yang dapat digunakan dalam pembinaan turapan di masa hadapan.

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LIST OF ABBREVIATIONS

F	-	Recovered Angle
G*/sin δ	-	Superpave™ rutting factor
G*	-	Complex shear modulus
δ	-	Phase angle
A	-	Thermal diffusivity
FT_U	-	High failure temperatures of unaged asphalt binder
E	-	Cumulative micro-strain
FT_S	-	High failure temperatures of short-term-aged asphalt binder
G’	-	Elastic component or storage modulus
G’’	-	Viscous component or loss modulus
J_{nr}	-	Creep compliance
Ω	-	Average angular recovery speed
$[\nabla M_R]_A$	-	Rate of aging effect on resilient modulus due to long-term aging condition at 25℃
$[\nabla M_R]_T$	-	Rate of test temperature effect on resilient modulus
ΔM_R	-	Difference in resilient modulus
∇M_R	-	Resilient modulus gradient
γ	-	Ratio of the strain
σ	-	Constant applied load
PI	-	Penetration index
S.P	-	Softening point
Au	-	Gold
C	-	Carbon
S	-	Sulfur
Pt	-	Platinum
CI	-	Chorine
SI	-	Silicon
O	-	Oxygen
Na	-	Sodium

LIST OF SYMBOLS

A	-	Aging
AI	-	Specific heat
AI	-	Asphalt Institute
AASHTO	-	American association of state highway and transportation officials
ASTM	-	American society for testing and materials
ANOVA	-	Analysis of Variance
AC	-	Aging Condition
BT	-	Asphalt Binder Type
BPSC	-	Batu Pahat Soft Clay
CGN	-	Compaction Gyration Number
DSR	-	Dynamic Shear Rheometer
DG	-	Dense-Grade
ESALs	-	Equivalent Single Axle Loads
G_{sb}	-	Bulk Specific Gravity of Aggregate
G_b	-	Specific Gravity of Asphalt
G_{se}	-	Effective Specific Gravity of Aggregate
G_{mb}	-	Specific Gravity of Aggregate
G_{mm}	-	Maximum Specific Gravity of Paving Mixture
HMA	-	Hot Mixture Asphalt
ITS	-	Indirect Tensile Strength
MSCR	-	Multiple Stress Creep Recovery
MT	-	Mixing Temperature
$N_{initial}$	-	Compaction Parameter
N_{design}	-	Compaction Parameter
$N_{maximum}$	-	Compaction Parameter
NAPA	-	National Asphalt Pavement Association

SHRP	-	Strategy Highway Research Program
OBC	-	Optimum Bitumen Content
P_{be}	-	Effective Asphalt Content, percent by total weight of Mixture
P_b	-	Asphalt. Percent by total weight of mixture
PG	-	Performance Grade
RTFO	-	Rolling Thin Film Oven
RV	-	Rotational Viscometer
SMA	-	Stone Matrix Asphalt
SFE	-	Surface Free Energy
STA	-	Short-Term-Aging
SGC	-	Superpave Gyratory Compactor
TSR	-	Tensile Strength Ratio
UTM	-	Universal Testing Machine
VFA	-	Voids Filled Asphalt
VMA	-	Voids Mineral Aggregate
VTM	-	Voids in Total Mixture

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