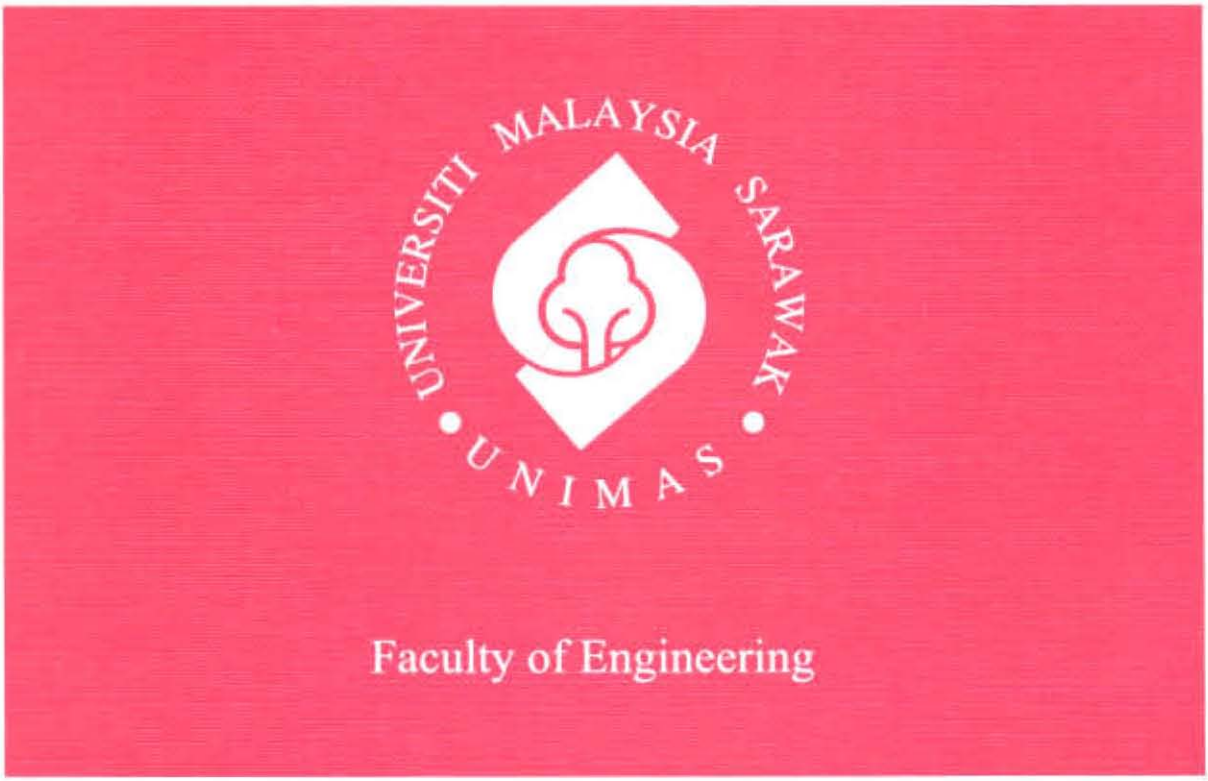

EVALUATING ON PROPERTIES OF DIFFERENT GRADES BITUMEN USING STRATEGIC HIGHWAY RESEARCH PROGRAM (SHRP) TEST METHOD

Nurkhadizah Binti Salleh

Bachelor of Engineering with Honours
(Civil Engineering)
2017

UNIVERSITI MALAYSIA SARAWAK

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EVALUATING ON PROPERTIES OF DIFFERENT GRADES BITUMEN USING STRATEGIC HIGHWAY RESEARCH PROGRAM (SHRP) TEST METHOD

NURKHADIZAH BINTI SALLEH

This project is submitted in partial fulfilment of
The requirement for the degree of
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Special dedication to:

My beloved Father and Mother,

Salleh Bin Pauzi and Masniah Intan Tan Bte Abdullah

and my dearest siblings, Meor Hakeem, Annastesia Sulastri, Adzran Cairul and Ghadafi, & my supportive friends

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ABSTRACT

Sarawak has been adopting bitumen penetration grade 80/100 for many years. The State Government has been allocated huge amount of money for maintaining major roads in Sarawak annually was due to pavement premature failure. Inappropriate grade of bitumen specified can be one of the causes of failure thus, it is crucial to consider properties of the bitumen as a quality control measure in a bituminous mixture construction. Evaluation on appropriate grade of bitumen binder that merit current characterization is of interest in this study. The study is intend to evaluate and compare physical properties of original bitumen and aged bitumen, grade 60/70 and 80/100 by using SHRP test method.

In this study, the fundamental rheological and mechanical tests were conducted, which include penetration test, softening point, rotational viscometer (RV) test, the rolling thin film oven test (RTFOT), and pressure age vessel (PAV). The effects of aging on the rheological and physical properties of bitumen binders then studied by conducting the Direct Shear Rheometer (DSR) test.

Laboratory test results observed that bitumen penetration grade 60/70 shows better performances compare to bitumen penetration grade 80/100 by perform higher viscosity, slowly aging during the mixing and layering process and higher resistance to pavement deformation and fatigue cracking failure. Higher viscosity will provide a higher quality of bituminous mixture since a viscous material has a good coating characteristic, slowly aging during the mixing and layering work provide a proper coating and workability in producing bituminous mixture, and with a higher capability to resist pavement deformation and fatigue cracking failure resulting in increases the pavement service life. Hence, longer pavement service lives at the same time help to address the issues of premature pavement failure and reducing the state cost for maintenance work. Since a heavy trafficked road functional to serve a higher number of road loading, bitumen penetration grade 60/70 is suitable and preferable to be used for the construction.

ABSTRAK

Sarawak telah menggunakan bitumen bergred PEN 80/100 semenjak dahulu lagi. Kerajaan Negeri Sarawak telah memperuntukkan jumlah wang yang besar setiap tahun bagi tujuan membaiki jalan yang disebabkan oleh kegagalan turapan di awal usia perkhidmatan. Gred bitumen yang tidak sesuai adalah merupakan salah satu punca kepada kegagalan turapan di awal usia. Dengan itu, ia adalah penting bagi mempertimbangkan sifat bitumen sebagai langkah kawalan kualiti dalam campuran bitumen. Penilaian gred yang sesuai sebagai pengikat bitumen yang menepati keadaan semasa adalah kepentingan dalam kajian ini. Kajian ini adalah bertujuan untuk menilai dan membandingkan sifat-sifat fizikal bitumen asal dan bitumen berusia, gred 60/70 dan 80/100 dengan menggunakan kaedah ujian SHRP.

Dalam kajian ini, ujian asas reologi dan mekanikal telah dijalankan, termasuk "*penetration test"*, "*softening point test*", "*rotational viscometer (RV) test*", "*the rolling thin film oven test (RTFOT),* dan *pressure age vessel (PAV).* Kesan-kesan penuaan pada sifat-sifat reologi dan fizikal pengikat bitumen kemudian dikaji dengan menjalankan ujian "*Direct Shear rheometer test"* (DSR). Keputusan ujian makmal membuktikan bahawa gred bitumen PEN 60/70 adalah berkelakuan lebih baik dengan menunjukkan kelikatan yang lebih tinggi, penuaan yang perlahan semasa proses penggaulan dan lapisan dan juga rintangan yang lebih tinggi terhadap kegagalan aluran turapan dan keretakan turapan. Kelikatan yang lebih tinggi akan memberikan campuran bitumen yang berkualiti tinggi kerana bahan likat mempunyai ciri salutan yang baik, penuaan yang perlahan ketika kerja pengaulan dan lapisan menyediakan campuran bitumen yang mudah digaul, dan dengan keupayaan yang lebih tinggi untuk melawan kegagalan aluran turapan dan keretakan turapan mengakibatkan peningkatan tempoh operasi turapan. Oleh itu, khidmat turapan yang lebih lama membantu untuk menangani masalah kegagalan turapan pra-matang dan mengurangkan kos negeri dari segi kerja-kerja penyelenggaraan. Memandangkan jalan bertransaksi yang berat berfungsi untuk memberikan lebih banyak pemuatan beban, bitumen 60/70 adalah sesuai dan lebih baik untuk digunakan bagi pembinaan.

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CHAPTER 1

INTRODUCTION

1.1 Background of Study

There are growing concerns over poor quality bitumen on road pavements in Malaysia. Bitumen quality has significant impact on pavement performance and directly affected its design life. Basically, road pavement design with 10 to 20 years' design life. Hence, throughout its service life, road pavement surface is widely exposed under combined actions of traffic and environment that affect the pavement performance which leads to pavement distress (Wee, Chan, & Teo, 2009). Pavement modes of distress that are encountered such as low temperature cracking, permanent deformation, fatigue cracking and aging are related with bituminous properties. Those type of failure influence by few condition such as low temperature cracking occur as bitumen becomes brittle and pavement shrinks in cold weather, permanent deformation alias rutting occur due to high temperatures as bitumen softens and mix loses its elasticity properties, and fatigue cracking occur due to excessive traffic loading applications and aging of the bitumen.

Hence, in order to control pavement distress and premature bitumen pavement failures, Strategic Highway Research Program (SHRP) method was developed (U.S. Department of Transportation, 2000). Superpave acronyms for Superior Performing Asphalt Pavements are the final product of the Strategic Highway Research Program (SHRP). With this grading system, accurate and fully characterized binders for use in bitumen pavement can be determined. Different grade of binder is designed for different environment to which the pavement structure will be exposed. For all this while, Sarawak has been using soft-grade paving bitumen penetration grade 80/100 for bituminous bases and wearing courses of bitumen pavements. An increase in the number of traffic loads and tropical climate weakens the pavement performance and

shorten its service of life. Pavement with weakened characteristic tends to crack and penetration of water through this crack will cause further weakening and finally will result in pavement failures. Thus, technical solutions to the problem of mitigation of rutting of surface layers and to increase the rigidity of the base courses of bitumen pavements should be developed.

1.2 Problem Statement

One of the main challenges faced by the State Government is to allocate a huge amount of money for maintaining major roads in Sarawak annually due to pavement distress problem which occurred prematurely. Based on Radzi, Harun, & Hanafi, (2010) studied, most of the road that had been completed within less than one year period will tend to experience premature failure which predominantly in the form of fatigue cracking. Despite the huge amount of money has been spent, pavement distress tends to reoccur even though resurfacing works has been done several time and end up in failures. Radzi, Harun, & Hanafi (2010) stated that inappropriate grade of bitumen specified are one of the possibilities for the failure. It is crucial to consider properties of the bituminous binders and the bitumen content as a quality control measure in a bituminous construction. Heat, air, moisture and sun light are the main factors which changes negatively engineering properties of the asphalt binders (Wu et al., 2008). SHA, Q.L, (2008), indicated that early damage of bituminous pavement is generally caused by several factors, such as the material's properties, construction method, construction quality, harsh environment, traffic volume and loads, while Wang (2012) found that the unsuitable design method of bituminous mixture is also considered as main reason causing the early damage of bituminous mixture. Thus, the construction sector should be interested in using the right type of bitumen for obtaining durable pavements (Nagabhushana, 2009).

In the other hand, Sarawak still practising bitumen grading on the basis of penetration grading system, which is conducted at a temperature of 25°C, and 80/100 penetration grade bitumen binder which has been used for many years**..** Up to now, innovation to new grade of bitumen binder which increases the rigidity of the wearing and base courses of bitumen pavements has not been done. With a strong increase in heavy vehicle traffic at the time, the search for a higher rigidity and a better resistance of the bituminous mixture to plastic deformations (rutting) led to the use of harder

bitumen binder. Thus, evaluations on appropriate grade of bitumen binder that merit current characterization is of interest in this study and at the same time addressing the issue of pavement distress in Sarawak. Bitumen with 80/100 and 60/70 penetration grade binders will be used in this studies. Basically, penetration grade of 60/70 bitumen is hardest than 80/100 and it has a higher tolerance to higher temperatures and better resistance to road deformation. In this study, investigation on the physical and rheological properties of these two bitumen grade as well as the comparison will be carried out and the best grade of penetration bitumen will be notified.

In order to accomplish this study, SHRP system appear to be the suitable method to applied to differentiate the suitable bitumen binder that meet current characterize since this system can classified each binders properties through varies standard testing. Superpave is a broad system for the design of the mix adapted by the unique performance requirements specified traffic, the environment (climate), and the structure in the pavement site. It improves the pavement performance through the selection and combination of the most suitable asphalt binder, aggregate, and, where necessary, modification of all possible option (National Research Council Washington, 1994).

1.3 Research Questions

This study aimed to address the following research questions:

i. What is the quality performance of Sarawak bitumen grade 60/70 and 80/100 by using SHRP test method?
ii. Which of the two different grades of bitumen is more suitable for building heavy trafficked roads in Sarawak?

1.4 Aims and Objectives

The aim of the study is to evaluate the suitability of different grade of bitumen for high loading road construction in Sarawak. The specific objectives of the study are to:

i. Evaluate the performance of bitumen grade 60/70 and 80/100 using SHRP test method.
ii. Compare the suitable grade for construction of heavy trafficked roads in Sarawak.

1.5 Chapter Organisation

This section comprises 5 chapters which are Introduction, Literature Review, Methodology, Result and Discussion and Conclusion. This section simplifies each chapter and provides the readers with specific information. The first chapter briefly describes Background of the Study, Problem Statement, Research Questions and Aim and Objectives. Second chapter review the bitumen properties and SHRP binder test based on past studies. Next, Chapter 3 provides the methodology and research framework used in this project. The method to carry out the experiment is provided in this chapter followed by parameters and its detail that needed. Thus, flow chart of study is presented to show the sequence of work or procedure that need to be carried out in this study.

Chapter 4 discusses all the collected data and results from laboratory test conducted in this study. Lastly, Chapter 5 provides the conclusions and recommendations for improvement and future usage of SHRP for Highway Industry in Sarawak.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter intends to review the SHRP methods of grading or classifying bitumen binders and types. In this study, SHRP method used as a measurement tool to the appropriate selection of bitumen grade binder that suit to local climate and traffic conditions of high roadway paving. The purpose of SHRP method is to establish and makes improvement in the areas of highway operations and to study the properties of bitumen and long term pavement performance. Hence, in this chapter, several past studies will be reviewed on how the performance based specifications of Superpave are used to improve pavement performance. The results of some laboratory experiments carried out on samples of bitumen obtained from different bitumen plants in the country will be reported and discussed.

2.2 Bitumen Structure

According to Tom & K V (2007), bitumen is black coloured semi-solid or viscous cementations substances consist of high molecular weight of hydrocarbons extract from distillation of petroleum or natural bitumen. However, Dasril & Jasni (2013) stated, not all crudes contain heavy hydrocarbon depends on bitumen origins, types and sources, fractions which is the essential component in making bitumen. Bitumen is predominantly used in roadway construction due to the unique characteristics such as viscoelastic, adhesive and outstanding binding characteristics, water proofing properties and relatively low cost (Asphalt Institute, 2007). Manolis (2014) studies that bitumen binder is occupying the space between aggregates in bituminous pavement mix and acts as the glue to bind the aggregates together and when the mineral aggregate is hold

together with bitumen binder, it conducts the strength and toughness to the bituminous mixture system.

Penetration grades empirically correlated with bitumen binder performance. In the hot climatic zone, lower penetration grades of bitumen are selected to resist rutting potential and at the same time to avoiding bitumen from softening. While for cold climate zone, higher penetration grades of bitumen are preferable to resist cracking potential and to avoid the incident of excessive brittleness. Surveys such as that conducted by Latif & Ibrahim Kamaruddin (2007) showed that Malaysia is the only Asian country that widely adopting bitumen penetration grade 80/100 instead of 60/70. However, Habibu (2017) recently reporting that bitumen penetration grade 60/70 will start to be used this May in Malaysia and at the same time the production of bitumen penetration grade 80/100 will be reduced. Changes are made to reduce road failures including potholes. The decision is made up based on foreign study that shows bitumen penetration grade 60/70 could sustain higher traffic load up to 21 percent and increase the pavement life span up to 18 percent. In addition, the resurfaced road would experience a higher modulus stiffness since the bitumen penetration grade 60/70 properties is more thickened compare to grade 80/100.

2.3 Bitumen Properties

Bitumen can be characterized by chemical composition and physical properties. Typically, the pavement industry is relying on binder physical properties for performance characterization. U.S. Department of Transportation (2000) indicated the most important bitumen physical properties consist of four elements which are durability, rheology, safety and purity. While Apparao, Rajesh & Raju (2013) reported, three physical properties of asphalt are important for engineering and construction purposes which are consistency, purity and safety and he then summarized there is no use to examine bitumen on purity and safety aspects, although the consistency property of bitumen should be graded. Hence, this study is only focusing on examining bitumen consistency and rheology properties.

2.3.1 Bitumen Consistency

Consistency is parameter to measure bitumen degree of stiffness and the ability to flow. Bitumen can be classified as thermoplastic material which means it liquefy when heated and solidify when cooled. Bitumen binder is a thermoplastic material and its consistency changes with the temperature. Temperature susceptibility is the rate at which the consistency of bitumen changes with temperature and it is a very important parameter of bitumen binder (Khalil et al., 2009). Bitumen binder basically is highly temperature susceptible (change in properties with high temperature), where it state of solidness (stiffness) or liquidness which means the ability to flow is very much temperature sensitive. There are number of empirical test that can be done to measure bitumen consistency such as penetration, softening point, ductility et cetera and also by testing the fundamental property of bitumen such as viscosity.

2.3.1.1 Penetration Grading

Adedimila & Olutaiwo (2008), has emphasized that traditionally, an appropriate graded of bitumen binders for pavement construction is based on resistance to penetration or viscosity measures. First and foremost, bitumen grade is specified by the penetration test. Penetration grading presumption is that the less viscous the bitumen, the deeper the needle will penetrate. This penetration depth is empirically correlated with bitumen binder performance which is the binders with high penetration numbers called “soft” are used for cold climates while asphalt binders with low penetration numbers called “hard” are used for warm climates (Latif & Ibrahim Kamaruddin, 2007). Chin, (2005) has studied that most Asian country, adopting penetration graded specification for bituminous binder which concentrate on the low service temperature (25°C).

Somehow, in Asian region, the main failure mechanism is related to deformation at high service temperature which means that penetration graded bitumen can be more expose to rutting. Furthermore, penetration graded system typically does not cover any engineering parameters. Due to this limitation, Australia has come out with a system that is based on viscosity at 60°C. Viscosity is the material characteristic used to describe the resistance of liquids to flow. This system basically controls temperature susceptibility by controlling the bitumen flow at high and intermediate service

temperatures using the means of viscosity and penetration requirements. To constrain bitumen to an acceptable range of temperature susceptibilities, limits were put on the viscosity tests at 60°C and 135°C. Viscosity grading is a better grading system but it does not test low temperature bitumen binder rheology properties.

In the other hand, Zumrawi (2015) has study on the suitability in adopting viscosity grading system in performance and durability of flexible pavements in Sudan. The purpose of this study is to clarify the viscosity grading system is more realistic, reliable and practical compare to the existing penetration grading system. The results indicated that bitumen binders used in industry are highly temperature susceptible (change in properties with high temperature) yet they actually have satisfied the standards. Furthermore, the experimental test shows that bitumen binder with similar penetration grade resulted with different viscosity grades which is means a different bitumen viscosity performance at high and low temperatures. This study already achieves its purpose by proving that the viscosity grading system is more realistic, reliable and practical since the testing procedure is perform at varies temperature which is viscosity at 60ºC, 135ºC and penetration at 25ºC, which relate to the properties of bitumen at high pavement temperature, mixing temperature and average pavement service temperature. Recommendations have been made to implement the viscosity grading system in order to improve the quality, performance and durability of bituminous pavements in Sudan.

Other researchers, however, have looked at the disadvantages of this grading system. Hassan et. al.,(2008) indicated that viscosity grading system is the principal grading does not really show that low temperature bitumen binder rheology and thin film oven test residue viscosities were very differ although the bitumen binders has same viscosity grade. Thus, the bitumen binder did not have same behaviour after construction. To conclude, penetration grading system and viscosity grading system does not show that consistency of bitumen binders influenced by temperature. Due to limitation of these traditional grading systems in the ability to fully characterize bitumen binders for use in HMA pavements, thus Superpave were developed new binder tests and specifications.

The current grading system in the United States is known as the Performance Grading (PG) system. Performance grading (PG) specifications was developed to relate bitumen properties to field performance and allow the selection of appropriate bitumen for a specific climatic condition. Angelo (2012) study that the Superpave system offers solutions to pavement problems through a rational approach and this system builds from