DETERMINATION OF MIXING AND COMPACTING TEMPERATURES FOR HOT MIX ASPHALT

NOORAFIDAH BINTI ITHNIN

A project report submitted in partial fulfillment of the
requirement for the award of the degree of
Master of Engineering (Civil-Transportation and Highway)

Faculty of Civil Engineering
Universiti Teknologi Malaysia

NOVEMBER, 2008

ABSTRACT

Malaysia has been using bitumen grade of 80-100 penetration for many years. The typical mixing and compacting temperature has been normally set as 160°C and 140°C respectively based on experience for the lab procedure purpose. With the newly revised Specification of Roadwork 2007 by JKR, new bitumen grade had been introduced including grade 60-70 and some other types of modified bitumen. The objective of this study is to determine the appropriate mixing and compacting temperature for the bitumen grades by viscosity and correlation with other physical properties of bitumen. Rotational Brookfield Viscometer was used to determine the correct temperature for viscosity at 165°C and 135°C and at viscosity ranges of 0.17±0.02 and 0.28±0.03 Pa s for mixing and compacting, respectively as per ASTM D 2493. The result shows that the PEN 60/70 bitumen, PG 76 and PG 82 show higher mixing and compacting temperature than PEN 80/100. It also indicates that penetration shows close relationship with viscosity and could be used to determine the mixing and compacting temperatures.

ABSTRAK

Bitumen gred PEN 80-100 telah digunakan di Malaysia semenjak dahulu lagi. Suhu bancuhan dan pemadatan asphalt yang biasa digunakan masing-masing ialah 160°C dan 140°C berdasarkan kepada pengalaman dan prosedur biasa di makmal. Dengan pengenalan kepada Semakan Semula Spesifikasi Kerja Jalan 2007 oleh Jabatan Kerja Raya Malaysia, beberapa jenis bitumen baru diperkenalkan termasuk PEN 60-70 dan bitumen Terubahsuai. Objektif kepada kajian ini ialah untuk menentukan suhu bancuhan dan pemadatan bagi beberapa jenis bitumen yang biasa digunakan di Malaysia serta kajian ke atas kelikatan dan hubungkaitan dengan ciri-ciri fizikal bitumen.

Alat Rotational Brookfield Viscometer digunakan untuk menentukan suhu yang sebenar berdasarkan kelikatan pada suhu 165°C dan 135°C dan pada sela kelikatan 0.17±0.02 untuk bancuhan dan 0.28±0.03 Pa s untuk pemadatan sebagaimana ASTM D 2493. Keputusan menunjukkan bahawa bitumen PEN 60/70, PG 76 dan PG 82 menunjukkan suhu bancuhan dan pemadatan yang lebih tinggi berbanding bitumen PEN 80/100. Kajian juga menunjukkan nilai Penusukan menunjukkan hubungkait yang rapat dengan Kelikatan dan boleh digunakan untuk menentukan suhu bancuhan dan pemadatan asfal.

TABLE OF CONTENTS

CHAPTER ONE

INTRODUCTION

1.1 Research Background

Bitumen is a thermoplastic material and its consistency changes with temperature. According to Roberts *et al*, (1996), at 275^{o}F (135^{o}C) the bitumen viscosity is very low. This characteristic is not desirable as that could result in occasional tender mix problem during compacting. Their viscosity (stiffness) at the lowest service temperature in the other hand, are usually very high, resulting in low temperature shrinkage cracking.

In addition, Hunter (2000) noted that it is important to have knowledge of bitumen viscosity at certain key point during the manufacture and lay of mixture, particularly during aggregate coating and compacting of mixture because the physical aspect of bitumen at low temperature is hard and has high viscosity. This resembles a solid and brittle but at higher temperature it becomes liquid and low viscosity.

Currently in most countries around the world, bitumen are graded according to a number of traditional, and often empirical tests. For example in UK, penetration and softening point have long been the basis of the grading systems. Elsewhere, fundamental properties such as viscosity have also been specified. Based on these properties, binder supplier have built up experience of how different binder will comply with the specification (Claxton, 1996).

To date, a lot of changes on grades of bitumen used where new grades are introduced to cater for specific needs in construction, unknown modifiers and heavy duty mixes. However, the criteria which never change after decades of asphalt use is the needs on understanding the viscosity for determination of mixing and compacting temperature of bitumen.

ASTM D2493 *Calculation of Mixing and Compaction temperatures* was established for unmodified bitumen binders, which are Newtonian fluids at high temperatures as for unmodified binder, viscosity does not depend on shear rate.

Stuart, (2001) mentioned that standardized procedures for determining the mixing and compaction temperature to be used in the laboratory are based on the equiviscous principle, which was developed 30 to 40 years ago for unmodified asphalt binders. This principle states that the allowable compaction temperature range is the range that provides an asphalt binder viscosity from 250 to 310 mm^2/s. There are methods for determining appropriate laboratory mixing and compaction temperatures for mixtures modified binders, but they require additional mixture tests to be performed during mixture design. A methodology like the equiviscous principle greatly reduces the amount of mixture testing that needs to be performed.

1.2 Problem Statement

Bitumen grade of 80-100 penetration has been widely used in Malaysia for many years. It is important to have knowledge of bitumen viscosity during the manufacture and lay of mixture, aggregate coating and compaction of mixture because in nature bitumen is solid, brittle and high viscosity at low temperature, but becomes liquid and low viscosity at higher temperature. The typical mixing and compaction temperature has been normally set as 160°C and 140°C respectively base on experience during the lab procedure.

With the vast development of construction industry in Malaysia, JKR has introduced newly revised Specification of Roadwork 2007 which list new bitumen grade including modified bitumen. According to the changes, it is necessary to choose accurate typical mixing and compaction temperature as a lab procedure to ensure the effectiveness and workability of the bitumen. This leads to the objective to determine the appropriate mixing and compaction temperature for the bitumen grades.

Historically, standardized procedures for determining mixing and compaction temperature should be used in the laboratory for mixture design have not provided valid temperatures for many asphalt mixtures for neat and modified binder. The use of an incorrect laboratory mixing and compaction temperature as a basis for adjusting the temperature of a hot-mix asphalt plant has caused significant problems in the field. Therefore, paving contractors generally use plant temperatures recommended by the suppliers of modified binders

According to Stuart (2001), the advantage of determining the mixing temperature of particular bitumen is to produce a good quality mixture at reasonable operating cost as excessively high temperatures may damage the asphalt binder, generate fumes, cause asphalt binder draindown, and may lead to a low asphalt binder content in some mixtures. Compacting bitumen at too high a temperature also may result in hairline cracks and mix displacement and if the bitumen is compacted at too low a temperature, there is a risk that the bonds between the aggregate and the binder will break up, or that the aggregate will be crushed.

Determining the compacting temperature will help to controls bitumen viscosity which affects its ability to coat and provide adequate lubrication for aggregates to slides with each other and pack into dense mass during compaction.

According to Lu (1997), for the base (neat) bitumen and modified bitumen containing a low polymer content (3% by weight in his study), dynamic viscosity is relatively independent of shear rate, indicating that these binders have a purely viscous Newtonian flow. However the modification with a sufficiently high modifier (SBS) increases the degree of non-Newtonian behaviour of bitumen.

1.3 Aim and Objective of The Study

The aim of the study is to establish a graphical relationship between temperature and viscosity to increase accuracy for mixing and compacting temperature for neat and modified bitumen and eliminate unnecessary wastage of power and change of bitumen properties during construction stage.

The objective of this study is to determine the appropriate mixing and compaction temperature for various bitumen grades used in Malaysia. This study will also establish the relationship between the physical properties that is viscosity, penetration and softening point related to the mixing and compacting temperature.

1.4 Scope of the Study

The scope of the study focused on five types of bitumen including neat bitumen grade of 2 types of PEN 80-100 from various supplier, PEN 60-70 and two types of modified bitumen; PG 76 and PG 82. All type of bitumen were tested for their rheological properties, which viscosity by using Brookfield Rotational Viscometer, penetration test by using Penetrometer and softening point by using Ring & Ball Apparatus.

1.5 Significant of the Study

Based on the result obtained from this study, a more accurate temperature of the mixing and compacting of mixture using various type of bitumen are proposed to improve the performance of the bitumen.

1.6 Limitation of Study

The study covers the process which was done in the lab and using limited type of bitumen based on availability as per suppliers' specification. Therefore the data collected based on the handling of bitumen, the quality, modifier used, pollutant and others if any.

The procedures conducted were based on the Standard Test Method for Viscosity Determination of Unfilled Asphalt Using the Brookfield Thermosel Apparatus ASTM D4402-87(reapproved 2000), Penetration Test ASTM D 5 and Softening Point ASTM D 36. The tests are conducted in Makmal Pengangkutan, Universiti Teknologi Malaysia, Skudai, Johor.

1.7 Outline of Project

This project consists of five chapters. Chapter I presents the introduction of the study. It covers the problem statement, objectives, scope, significant and limitation of study. Chapter II describes the literature review of the project. It explains the general review of the bitumen properties and the behavior. Chapter III describes the methodology which was used to determine the mixing and compaction of variety of bitumen. Chapter IV discusses the result of laboratory experiment on the bitumen. Chapter V highlights the conclusion and recommendation on relationship between temperature of mixing and compacting of various type of bitumen and other factors.

REFERENCES

3.3 Materials – Asphalt (2003) website. Viewed on January 2008, <http://training.ce.washington.edu/wsdot/modules/03_materials/03-3_body.htm>

American Society for Testing and Materials. *Standard Viscosity-Temperature Chart for Asphalts* ASTM D2493.

American Society for Testing and Materials (1997). *Standard test method for penetration of bituminous materials*, ASTM D5, Philadelphia.

American Association of State Highway Official *Viscosity Determination of Asphalt Binder Using Rotational Viscometer* AASHTO TP48 .

Asphalt Institute (1990). "*Introduction to Asphalt*." Lexington, Kentucky, United States of America: Asphalt Institute, Research Park Drive.

Asphalt Institute (1990). "*Laboratory Mixing and Compaction Temperature*." Lexington, Kentucky, United States of America: Asphalt Institute, Research Park Drive.

Bahia, H. U., Hanson, D. I., Zeng, M., H., Khatri, M. A., and Anderson, R. M. (2001), *Characterization of Modified Asphalt Binders in Superpave Mix Design" National Cooperative Highway Research Program, Rep. No. NCHRP 459*, National Acedemy Press, Washington D.C

BP(2008) website. Viewed on Februari 2008
<http://www.bp.com/liveassets/bp_internet/bitumen/.../downloads_pdfs/s/sources.pdf>

Claxton & Green, P.J, (1997), *The Classification of Bitumens and Polymer Modified Bitumens Within the SHRP Performance Grading System*, BP Oil International,UK.

Hunter, R.N. (2000). A*sphalt In Road Construction*. Thomas Telford Limited, London.

Hunter, R.N. (2003). *The Shell Bitumen Handbook Fifth Edition*., Thomas Telford Limited, London.

James, H. Banks, *Introduction to Transportation Engineering*, Houbslow Books, London, Mdx, UK.

Jabatan Kerja Raya (JKR) (2005). *Standard Specifications for Road Works*. Kuala Lumpur, Malaysia, JKR/SPJ/rev2005.

Lee, M. G., Chiu, C. T., Kan., Y. C., Chen., K. C., *Comparison of Results of SHRP and Conventional Binder Tests on Paving Asphalts*, International Journal of Applied Science and Engineering, 2004. 245-256.

Roberts, L.F., Kandhal, P.S., Brown, R.E., Lee, D.Y., Kennedy, T.W. (1996). *Hot Mix Asphalt Materials, Mixture, Design and Construction.* NAPA Education Foundation. Maryland.

Stuart, Kevin. D., (2002), *Methodology of Determining Compaction Temperature for Modified Asphalt Binder*, Federal Highway Administration, U.S Department of Transportation, Virginia.

Yetkin, Y. P. E. (2006). *Evaluation of Viscosity Values For Mixing and Compacting Temperature*. Journal of Materials In Civil Engineering@ASCE July/August 2006. 545-553.