PERFORMANCE OF SASOBIT MODIFIED ASPHALT BINDER IN WARM-MIX ASPHALT TECHNOLOGY

SHAHAB MOEINI FEIZABADI

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

Faculty of Civil Engineering
Universiti Teknologi Malaysia

January 2014

Families are the compasses that guide us. They are the inspiration to reach great heights, and our comfort when we occasionally falter. “Brad Henry”

To my father, mother and wife for your sacrifices…

AKNOWLEDGEMENT

I would like to express my very great appreciation to Dr. Md. Maniruzzaman B. A. Aziz for his helps and supervisions in this research project. His attention and support played a very important role in the shaping of this work.

Special thanks dedicated to HoD of JGP Professor Dr. Mohd Rosli Hainin and head of highway laboratory Dr. Norhidayah Abdul Hassan for their cooperation and permission for working in the lab even at weekends.

My special thanks are extended to SHELL, Singapore for donation of testing asphalt binders.

Many thanks are also due to laboratory technicians of UTM and UTHM for their cooperation during the lab works. I am grateful to all my colleagues, friends, staff, and lecturers in Universiti Teknologi Malaysia.

Lastly, I thank my parents, my wife and dear friends Mr Hamzeh Ali Poorbagher and Mr Manouchehr Shokri for their constant encouragement without which this study would not be possible.

ABSTRACT

Road maintenance is widely recognized, but not adequately maintained due to economic crisis of countries. Besides, increasing emission of greenhouse gases is an environmental issue, and it is a great concern to curb this problem from further harm to the environment and living things have captured attention of many parties, including pavement industries. Warm-mix asphalt (WMA) technologies could address the deterioration issues, reduce escalated energy costs, decrease global warming, reduce air pollution and increase environmental awareness. These matters have brought attention to the potential benefits of WMA in the developing countries. WMA technologies allow significant lowering of the production and paving temperature compared to conventional HMA (Hot-Mix Asphalt). In HMA production, the quarry mixing temperature is equivalent of asphalt's viscosity of 170cP (0.17Pa.s), and gets sufficient fluidity to coat all the aggregates properly, whereas paving temperature is equivalent of a viscosity of 280cP (0.28Pa.s). Sasobit is an organic additive of warm mix asphalt technology, which used in this study as an asphalt binder modifier. The rates of sasobit were from 0.4% to 3.2% with interval 0.4 by mass of the asphalt binder. Two types of penetration asphalt binder (800-100 and 60-70) were used. The tests which conducted were penetration test, Rotational Viscosity (RV) test and Dynamic Shear Rheometer (DSR) test. In addition, The Rolling Thin Film Oven (RTFO) and the Pressure Aging Vessel (PAV) simulate the asphalt binder's short-term aging and long-term aging respectively. Moreover, complex shear modulus (G*) was determined for finding the rutting factor (G/Sinδ) and fatigue factor (G*.Sinδ) for both asphalt binders. This study illustrates the optimum rate of sasobit is between 2.8 and 3.2% by weight of the asphalt binder.

ABSTRAK

Penyelenggaraan jalan diiktiraf secara meluas, tetapi ianya tidak dijalankan dengan baik disebabkan oleh krisis ekonomi sesebuah negara.. Selain itu, pelepasan gas rumah hijau merupakan salah satu isu alam sekitar, dan ia adalah satu masalah yang sukar untuk dibendung daripada membahayakan alam sekitar dan ini telah menarik perhatian banyak pihak termasuk industri pembuatan jalan. Teknologi asfalt campuran suam (Warm Mix Asphalt, WMA) boleh menangani isu-isu kerosakan jalan, mengurangkan kos tenaga, mengurangkan pemanasan global, mengurangkan pencemaran udara dan meningkatkan kesedaran tentang alam sekitar. Perkara-perkara ini telah membawa perhatian kepada potensi WMA di negara-negara membangun. Teknologi WMA boleh mengurangkan pengeluaran dan suhu turapan berbanding asfalt campuran panas (Hot -Mix Asphalt, HMA). Dalam pengeluaran HMA , suhu pencampuran di kuari adalah bersamaan kelikatan asphalt 170cP (0.17Pa.s) , dan mendapat sifat kecairan yang cukup untuk menyalut semua agregat dengan betul, manakala suhu turapan adalah sama dengan kelikatan 280cP (0.28Pa.s). Sasobit adalah bahan tambahan organik kepada teknologi WMA yang digunakan dalam kajian ini sebagai pengubahsuai pengikat asfalt. Kadar sasobit adalah dari 0.4% kepada 3.2% dengan selang 0.4 oleh jisim pengikat asfalt. Dua jenis kadar penembusan asfalt pengikat (800-100 dan 60-70) telah digunakan. Ujian yang dijalankan adalah ujian penembusan (penetration test), ujian putaran Kelikatan (Rotational Viscosity, RV) dan ujian dinamik ricih reometer (Dynamic Shear Rheometer, DSR). Di samping itu, Rolling Thin Film Oven (RTFO) dan Pengandung Tekanan Penuaan yang (Pressure Aging Vessel, PAV) masing-masing menunjukkan penuaan jangka pendek dan penuaan jangka panjang pengikat asfalt. Selain dari itu , modulus ricih kompleks (G*) digunakan untuk mencari faktor aluran (G*/Sinδ) dan faktor keletihan (G*.Sinδ) bagi kedua-dua pengikat asfalt. Kajian ini menunjukkan kadar optimum sasobit adalah antara 2.8 dan 3.2 % mengikut berat pengikat asphalt.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS AND SYMBOLS

%	-	Percentage
G*	-	Complex Shear Modulus
δ	-	Phase Angle
WMA	-	Warm-Mix Asphalt
HMA	-	Hot-Mix Asphalt
PG	-	Performance Grade
PEN	-	Penetration
RAP	-	Reclaimed Asphalt Pavement
HAP	-	Hazardous Air Pollution
FT	-	Fischer-Tropsch
RPM	-	Revolutions per Minute
RV	-	Rotational Viscometer
DSR	-	Dynamic Shear Rheometer
RTFO	-	Rolling Thin Film Oven
PAV	-	Pressure Aging Vessel
AASHTO	-	American Association of State Highway and Transportation Officials
ASTM	-	American Society for Testing and Materials
NAPA	-	National Asphalt Pavement Association
NCAT	-	National Center for Asphalt Technology
UN	-	United Nations
WHO	-	World Health Organization

CHAPTER 1

INTRODUCTION

1.1. Background of the Study

The need of understanding the effects of global warming and air pollution have been realised worldwide. Furthermore, increasing emission of greenhouse gases is an environmental issue, and it is a great concern to curb this problem from further harm to the environment and living things have captured attention of many parties, including pavement industries. Warm-mix asphalt (WMA) is one of those efforts to curb a reduction in the temperature at which asphalt mixes are produced and placed.

Primary experiments on warm-mix asphalt technology were started in European countries by 1995.[1] Since 1997, over 142 projects were paved using Sasobit® totalling more than 2,271,499 square meters of pavement. Projects were constructed in Austria, Belgium, China, Czech Republic, Denmark, France, Germany, Hungary, Italy, Macau, Malaysia, Netherlands, New Zealand, Norway, Russia, Slovenia, South Africa, Sweden, Switzerland, the United Kingdom, and the United States.[2] By 2002, NAPA started a study tour to Europe. Between years 2002 and 2007 NAPA, NCAT and AASHTO published some research on WMA technology including sasobit.[1]

Sasobit is produced by Sasol Wax Company in South America and Germany. It is also known as FT paraffin wax or asphalt flow improver. Sasobit is completely soluble in asphalt binder. Sasobit has different effect on asphalt binder viscosity. Above its melting point the wax reduces the binder viscosity but observed at lower temperature ranges, when the asphalt binder is in the colloid or the solid phase, which asphalt binder viscosity increases.[2]

The effect of wax depends on the chemical composition and the rheological characteristics of the asphalt binder, the composition crystallinity of the wax, the application temperature range, and the amount of wax.[2] In addition, sasobit blending rate is very important and past research show that more than 4% sasobit content has a damaging effect on asphalt binder.[3] That is why, in some countries such as Germany, France, and China, the amount of wax in the asphalt binder is restricted.[2]

1.2. Problem Statement

Asphalt binder plays an important role in road construction as a typical binder. In this process, heating is required to handle bitumen due to its high viscosity. Unfortunately, this fact involves some energetic, environmental and health problems like fume emissions. Furthermore, modern traffic with a large number of trucks and increased tire pressure, offers a serious challenge to the design, construction and maintenance of asphalt pavements through of the world. Around one billion USD is spent annually for the repair of potholes. In addition, each particular failure mechanism is a function of asphalt's basic intermolecular chemistry. Currently, not enough asphalt chemical knowledge to adequately predict performance. That is why physical properties and tests are used. Until now, we are unable to know the chemical formula for asphalt binder.

1.3. Objectives of the Study

The main research objectives of this research are:

i. The effect of Short-term and long-term aging on the penetration and viscosity of asphalt binders 80-100 and 60-70

ii. The effect of various percentages of sasobit on the penetration and viscosity of the original (unaged), short-term and long-term aged asphalt binders 80-100 and 60-70 and finding the viscosity of high temperature asphalt binders 80-100 and 60-70 at different aging phases.

iii. Illustrating the G*/Sinδ (rutting factor) and G*.Sinδ (fatigue factor) of above asphalt binders at different temperatures.

iv. Determining the optimum application rate of sasobit in both asphalt binders due to penetration, viscosity, fatigue and rutting factor

1.4. Scope of the project

The effect of sasobit on different aging phases was investigated in this research. In Malaysia, use of 80-100PEN is very common. However, the 60-70 PEN is recommended in the new JKR specification. In this study these two types of penetration asphalt binders evaluated with sasobit modification which, both of them were brought from SHELL, Singapore. Figure 1.1 shows the asphalt binder 60-70 using in this study. The dosages of sasobit were from 0.4 to 3.2 with interval 0.4 by mass of asphalt binder. Figure 1.2 illustrates the sasobit of this project. Short- term and long-term aging were simulated with the Rolling Thin Film Oven test (RTFO) and the Pressure Aging Vessel test (PAV) respectively. Penetration test, Rotational Viscosity test (RV) and Dynamic Shear Rheometer (DSR) were used to determine some physical and rheological properties of virgin and modified asphalt binder. It should be noted that DSR tests were done in highway laboratory of Universiti Tun Hussein Onn Malaysia (UTHM).

1.5. Thesis Organisation

This thesis is divided into five chapters. Chapter 1 provides a general overview of the study. Literature review on Warm-mix asphalt technology and discussion about modifies sasobit asphalt binder is presented in Chapter 2. The experimental set up and techniques used are explained in Chapter 3. All the experiments data and results are presented in Chapter 4. The finding and discussion about the results also presented in this chapter. Finally, Chapter 5 is the conclusion and recommendation for future work. Figure 1.3 illustrates the discussion flowchart of this study.

Figure 1.1: Asphalt binder 60-70 using this study

Figure 1.2: Sasobit using in this project

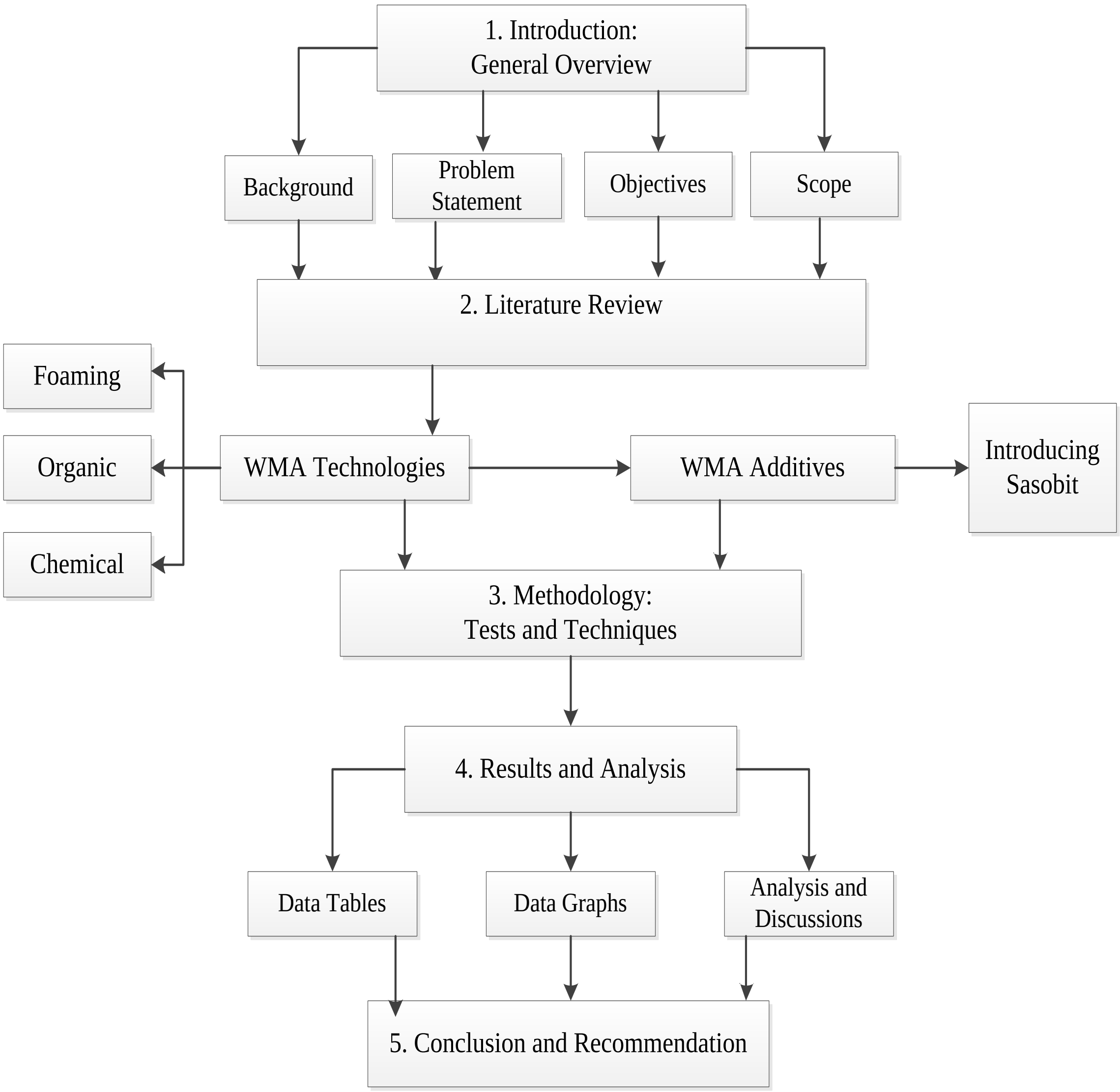

Figure 1.3: Discussion flowchart of this project

REFERENCES

1 Prowell, BD, Hurley, GC and Frank, B (2007) “Warm-mix asphalt: Best practices.”

2 Jamshidi, Ali, Hamzah, Meor Othman and You, Zhanping (2013) “Performance of Warm Mix Asphalt containing Sasobit®: State-of-the-art.” *Construction and Building Materials*, 38, pp. 530–553.

3 Wasiuddin, Nazimuddin M, Saha, Rajan, King, William and Mohammad, Louay (2012) “Effects of Temperature and Shear Rate on Viscosity of Sasobit ® -Modified Asphalt Binders.” , 5(6), pp. 369–378.

4 Hassan, Marwa (2009) “Life-cycle assessment of warm-mix asphalt: an environmental and economic perspective.” *Transportation Research Board*.

5 Intergovern Mental Panel on Climate Change (2007) “IPCC2007.”

6 United Nations “NBC News.”

7 Change, Climate “Protecting health from Climate Change : The Global Response.” , pp. 1–25.

8 Asphalt, Northeast and Group, User-producer (2003) “Warm Mix Asphalt Technology Advantages of Lower.”

9 Shu, Xiang, Huang, Baoshan, Shrum, Emily D. and Jia, Xiaoyang (2012) “Laboratory evaluation of moisture susceptibility of foamed warm mix asphalt containing high percentages of RAP.” *Construction and Building Materials*, 35, pp. 125–130.

10 Hamzah, Meor Othman, Jamshidi, Ali and Shahadan, Zulkurnain (2010) “Evaluation of the potential of Sasobit® to reduce required heat energy and CO2 emission in the asphalt industry.” *Journal of Cleaner Production*, 18(18), pp. 1859–1865.

11 Aspha-min, The (2007) “Warm Mix Asphalt Technologies.”

12 Rubio, M. Carmen, Martínez, Germán, Baena, Luis and Moreno, Fernando (2012) “Warm mix asphalt: an overview.” *Journal of Cleaner Production*, 24, pp. 76–84.

13 Gandhi, Tejash (2008) “Effects of Warm-mix Additives on Asphalt Binder”

14 Capitão, S.D., Picado-Santos, L.G. and Martinho, F. (2012) “Pavement engineering materials: Review on the use of warm-mix asphalt.” *Construction and Building Materials*, 36, pp. 1016–1024.

15 Das, Animesh (2004) “Warm mix asphalt.” *iitk.ac.in*, pp. 3–4. 16 Zaumanis, Martins (2010)

17 AQUA black solution “Retrofit any batch or drum.”

18 Dinis-Almeida, M., Castro-Gomes, J. and Antunes, M.L. (2012) “Mechanical Performance and Economic Evaluation of Warm Mix Recycling Asphalt.” *Procedia - Social and Behavioral Sciences*, 53, pp. 286–296.

19 Dinis-Almeida, Marisa, Castro-Gomes, João and Antunes, Maria De Lurdes (2012) “Mix design considerations for warm mix recycled asphalt with bitumen emulsion.” *Construction and Building Materials*, 28(1), pp. 687–693.

20 Mo, Liantong, Li, Xun, Fang, Xing, Huurman, M. and Wu, Shaopeng (2012) “Laboratory investigation of compaction characteristics and performance of warm mix asphalt containing chemical additives.” *Construction and Building Materials*, 37, pp. 239–247.

21 Xiao, Feipeng, Punith, V.S. and Amirkhanian, Serji N. (2012) “Effects of non-foaming WMA additives on asphalt binders at high performance temperatures.” *Fuel*, 94, pp. 144–155.

22 Zaumanis, Martinsh and Haritonovs, Viktors (2010) “Research on properties of warm mix asphalt.” *Riga Technical University, Series 2:* 11, pp. 77–84.

23 AASHTO (2005) “Warm Mix Asphalt”

24 Akisetty, Chandra K., Lee, Soon-Jae and Amirkhanian, Serji N. (2009) “High temperature properties of rubberized binders containing warm asphalt additives.” *Construction and Building Materials*, 23(1), pp. 565–573.

25 Engineer, Transportation, Muench, T, Michael, Larry, Consulting, Technology, et al. (2007) , pp. 1–9.

26 Hurley, GC and Prowell, BD (2005) “Evaluation of Sasobit for use in warm mix asphalt.” *NCAT report*

27 Report, Final (2009) “Synthesis of Warm Mix Asphalt Paving Strategies for Use in Montana Highway Construction.” , (November).

28 Report, Technical, Page, Documentation and Covered, Period (2008) “A Review of Warm Mix Asphalt December 2008 6.” , 7(2).

29 Valley, Hunt (2007) “TWG – Warm Mix Asphalt.”

30 Bueche, Nicolas (2009) “Warm asphalt bituminous mixtures with regards to energy , emissions and performance.”

31 D. Jones, B.W. Tsai and J. Signore (2010) “Warm - Mix Asphalt Study : Laboratory Test Results.”

32 D’Angelo, John A. (2008) “Warm Mix Asphalt Technology.”

33 Diefenderfer, SD, McGhee, KK and Donaldson, BM (2007) “Installation of warm mix asphalt projects in Virginia.” , (434).

34 Wang, Hainian, Dang, Zhengxia, You, Zhanping and Cao, Dongwei (2012) “Effect of warm mixture asphalt (WMA) additives on high failure temperature properties for crumb rubber modified (CRM) binders.” *Construction and Building Materials*, 35, pp. 281–288.

35 Qin, Qian, Farrar, Michael J., Pauli, Adam T. and Adams, Jeramie J. (2013) “Morphology, thermal analysis and rheology of Sasobit modified warm mix asphalt binders.” *Fuel*, 115, pp. 416–425.

36 Banerjee, Ambarish, de Fortier Smit, Andre and Prozzi, Jorge a. (2012) “The effect of long-term aging on the rheology of warm mix asphalt binders.” *Fuel*, 97, pp. 603–611.

37 Kridan, FAM (2011) “The effect of Warm Mix Asphalt Additive (Sasobit registered) Determination of Optimum Bitumen Content.” pp. 400–406.

38 Nazimuddin M. Wasiuddin, Selvaratnam Selvamohen, Musharraf M. Zaman and Marie Louise Therese Anne Guegan (2007) “1. Comprative Laboratory Study of Sasobit and Aspha-Min Additives in Warm-Mix Asphalt.pdf.”

39 Jamshidi, Ali, Hamzah, Meor Othman and Aman, Mohamad Yusri (2012) “Effects of Sasobit® Content on the Rheological Characteristics of Unaged and

Aged Asphalt Binders at High and Intermediate Temperatures 2 . Materials and Test Programs." , 15(4), pp. 628–638.

40 Zhao, Gui-juan and Guo, Ping (2012) "Workability of Sasobit Warm Mixture Asphalt." *Energy Procedia*, 16, pp. 1230–1236.

41 Sosol Wax (n.d.) "Sasobit Handling and Blending Guideline." , pp1–4.

42 Arshad, AK, Kridan, FAM and Rahman, MYA (2013) "The Effects of Sasobit® Modifier on Binder at High and Intermediate Temperatures." *doaj.org*, (3), pp. 81–84.

43 Yi-qiu, Tan, Lei, Zhang, Wei-qiang, Gong and Meng, Guo (2012) "Investigation of the effects of wax additive on the properties of asphalt binder." *Construction and Building Materials*, 36, pp. 578–584.

44 www.pavementinteractive.org

PUBLICATIONS

A. Conference Certificates

a. GEOCON2013 (GEOTROPIKA2013 and ICONBUILD2013)

b. ICoSEM2013 (1st International Conference on the Science & Engineering of Materials)

B. Conference Proceedings

1. ICoSEM2013, MRI IF: 1.3, A Review: Merits of Warm-Mix Asphalt Technology Using Sasobit and Aspha-min Additives

2. ISBN No. 978-967-0194-36-3: Proceeding of GEOCON, An Overall Review: Modified Asphalt binder Containing Sasobit in Warm-Mix Asphalt Technology

3. ISBN No. 978-967-0194-36-3: Proceeding of GEOCON, A Review on the Performance of Modified Asphalt Binder with Tire Rubber Powder

4. ISBN No. 978-967-0194-36-3: Proceeding of GEOCON, A Review on Performance of Steel Slag in Highway Surface Course

5. ISBN No. 978-967-0194-36-3: Proceeding of GEOCON, A Review of Steel Slag as a Road Construction Material Not an Industrial Waste