EFFECT OF AGGREGATE GRADATION ON POROUS ASPHALT PROPERTIES

FARAHIYAH BINTI ABDUL RAHMAN

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

Specialty dedicated to my beloved father and mother,

Abdul Rahman bin Wahab and Fatimah bt Jusoh

My siblings and all my families

All my friends

Thanks for your sacrifices and support……..

ACKNOWLEDGEMENT

Assalamualaikum w.b.t

Thanks to Allah SWT for his permission and blessings for me to complete my Master Project in a timely manner.

My deepest appreciation goes to my supervisor, *Dr. Ramadhansyah Putra Jaya* for his guidance and help. Thank for all the criticism and shared experiences to help me preparing this thesis. Further thanks also go to technicians of Highway and Transportation laboratories which is *En Sahak* and *En.Azri* and for all my friends especially *Thanwa, Nadhir and Ain,,* for their assistance and cooperation.

Last but not least, thanks to my beloved family who never give up in giving me encouragement and enthusiasm to finish my project. May ALLAH reward all of them for their kindness and sincerity. All the helps and sacrifices from all parties are unforgettable and really appreciated. I hope this project will be useful for future use. InsyaAllah……

ABSTRACT

Rainwater or storm water is very common in Malaysia and even at certain time, several places in this country will face the flooding problem. This condition will give a big trouble to the road in Malaysia as majority of them were made by asphaltic concrete. The run off from the rain water if it is not discharge as soon as possible will cause a lot of problem to the road user as well as for the condition of road itself. Based on the previous study, one of this problem solving is by using porous asphalt as wearing course of pavement. In order of that, this study was conducted to evaluate the effect of aggregate gradation on porous asphalt properties. The method is to compare the properties of Grading A and Grading B based on JKR specification (JKR/SPJ/2008) and binder used is PG76 bitumen. The void ratio of the test specimen was controlled in order to ensure the sufficient permeability of porous asphalt. There are several tests was conducted to evaluate properties of the specimen such as abrasion loss test, binder draindown test, resilient modulus test, creep test, and stability test. The test results indicated that gradation affected the performance and properties of porous asphalt mixtures. Grading B showed the best result in term of the physical properties and performance of porous asphalt mixture. The result from both gradations varies caused by difference of the aggregate size proportion of them. The difference aggregate size proportion resulted in difference arrangement of aggregate skeleton in mixture, thus affected the porosity of mixture. It will also affect an ability of granular to resist cyclic load from the pavement surface, and then affected the physical properties of them.

ABSTRAK

Air hujan atau ribut air adalah perkara biasa di Malaysia dan juga pada masa tertentu, beberapa tempat di negara ini akan menghadapi masalah banjir . Keadaan ini akan memberikan masalah besar kepada jalan raya di Malaysia kerana kebanyakkannya dibuat oleh campuran konkrit asfalt . Air hujan yang mengalir atas jalan jika ia tidak dialirkan secepat mungkin akan menyebabkan banyak masalah kepada pengguna jalan raya dan juga untuk keadaan jalan itu sendiri. Berdasarkan kajian sebelum ini, salah satu penyelesaian masalah ini adalah dengan penggunaan asfalt berliang sebagai turapan. Oleh itu, kajian ini telah dijalankan untuk menilai kesan penggredan agregat ke atas sifat-sifat asfalt berliang. Kaedah ini adalah untuk membandingkan sifat-sifat Penggredan A dan Penggredan B berdasarkan spesifikasi JKR (JKR/SPJ/2008) dan bahan pengikat yang digunakan adalah bitumen PG76. Nisbah lompang spesimen ujian telah dikawal bagi memastikan kebolehtelapan yang mencukupi bagi asfalt berliang. Terdapat beberapa ujian telah dijalankan untuk menilai sifat-sifat spesimen seperti ujian kehilangan lelasan, pengaliran bitumen, ujian modulus berdaya tahan, ujian rayapan (*Creep*), dan ujian kestabilan. Keputusan ujian menunjukkan bahawa penggredan menjejaskan prestasi dan sifat-sifat campuran asfalt berliang. Penggredan B menunjukkan hasil yang terbaik dari segi sifat-sifat fizikal dan prestasi campuran asfalt berliang. Nilai daripada kedua-dua penggredan ini berbeza disebabkan oleh perbezaan pembahagian saiz agregat mereka. Pembahagian saiz agregat mempengaruhi susunan agregat di dalam campuran, dengan itu menjejaskan keliangan campuran. Ia juga akan memberi kesan kepada keupayaan berbutir agregat untuk menentang beban dari permukaan jalan raya, dan kemudian memberi kesan kepada sifat-sifat fizikal mereka.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABREVATIONS

AASHTO	-	American Association of State Highway and Transportation Official
ASTM	-	American Society for Testing and Material
HMA	-	Hot Mix Asphalt
JKR	-	Jabatan Kerja Raya
OBC	-	Optimum Bitumen Content
PG	-	Performance Grade
TMD	-	Theoretical Maximum Density
VTM	-	Void Total Mix
VFB	-	Void Filled Mix
Mm	-	Milimeter

LIST OF SYMBOLS

G_{mb}	-	Bulk Specific Gravity
G_{mm}	-	Theoretical Maximum Density
g	-	Gram
°C	-	Degree Celsius
%	-	Percent
€		Strain

LIST OF APPENDIX

CHAPTER 1

INTRODUCTION

1.1 Background

Porous asphalt, also known as pervious, permeable, "popcorn," or open-graded asphalt, is standard hot-mix asphalt with reduced sand or fines and allows water to drain through it. Porous asphalt over an aggregate storage bed will reduce stormwater runoff volume and rate, thus reduce pollutants that carrying by the runoff water. The interconnected void space in the porous asphalt allows stormwater to flow through the asphalt, and enter a crushed stone aggregate bedding layer and base that supports the asphalt while providing storage and runoff treatment. When properly constructed, porous asphalt is a durable and cost competitive alternative compared to conventional asphalt (U.S. Environmental Protection Agency, 2009).

1.2 Problem Statement

The seasonal wind flow patterns coupled with the local topographic features determine the rainfall distribution patterns over the country. During the northeast

monsoon season, the exposed areas like the east coast of Peninsular Malaysia, Western Sarawak and the northeast coast of Sabah experience heavy rain spells (Malaysian Metrological Department, 2012). However this condition is not very good for the pavement condition in Malaysia as major of road and highway in this country is flexible pavement. Flexible pavements deteriorate under traffic loads and climate effects (Incegull and Ergun, 2011). Water on the road surface must be drained as soon as possible because it may contribute to accidents and reduce the service life of the material (Nursetiawan et al, 2008).

The weather also has an influence on road safety. Weather conditions partly determine the road conditions and the driver's behavior. Most studies into the relation between weather and road safety are about the situation during rainfall. Various measures have been taken to increase road safety, such as compulsory rear fog lamps, porous asphalt, and the introduction of slipperiness warning systems (Institute for Road Safety Research, 2012). However in this study porous asphalt pavement is taken into account to solve this particular problem.

1.3 Background Of Study

This study is focused on using the asphaltic porous pavement to solve the deteriorate pavement problem that cause by the water that coming from heavy rain. The pavement problem that caused by the climatic condition in Malaysia can be solve by using the asphaltic porous pavement.

Scientists and engineers who observe the complicated relationship between water and roadways have long understood the need for a sustainable method to simulate the natural filtration process of water or specifically rain water on road (pavegreen, 2012). In urban or other high-population areas, rainfall becomes runoff water and can contribute to flooding on roads and parking lots.

Porous asphalt is natural material that contains aggregate and bitumen that are bond together in certain condition, but there are a bit different from the usual asphalt. The difference is this type of pavement use is mostly coarse aggregate, so the spaces between them allow water to flow through it. Under this situation, porous asphalt pavement surface act as recharge bed that built of stones with a large spaces between them. Rainwater sinks through the pavement surface into the recharge bed, where it is retained until it can slowly filter out into the subsurface drain

1.4 Scope Of Study

The focus of this study is to compare the physical properties of porous asphalt pavement based on different gradations of aggregate. The test samples are made of the following material:

1. Grading A aggregate of Porous Asphalt that has nominal maximum aggregate size 14 mm that bind with PG76 bitumen.
2. Grading B aggregate of Porous Asphalt that has nominal maximum aggregate size 20 mm that bind with PG76 bitumen.

1.5 Aim And Objective

The aim of this study is to compare the properties of the porous asphalt based on the two different gradation of aggregate as mention on the scope of study above. From this study, the type of porous asphaltic pavement that has the value of design and in place air void 18% to 25% in the range will be identified to ensure drain-ability of the porous pavement (JKR Specification, 2008). It will be the best choice for the implementation of the porous asphalt pavement to solve the problem

mention in problem statement above. From the aim that mention above, there are several numbers of objective for this research:

1. To determine the optimum bitumen content of porous asphalt based on gradation of aggregate
2. To determine and compare the physical properties of porous asphalt at different gradation of aggregate

REFERENCE

ASTM Standard C127 – 12, Standard Test Method for Density, Relative Density (Specific Gravity), and Absorption of Coarse Aggregate1, Copyright © ASTM International

ASTM Standard C128 – 12, Standard Test Method for Density, Relative Density (Specific Gravity), and Absorption of Fine Aggregate1, Copyright © ASTM International

ASTM Standard D6927 − 06, Standard Test Method for Marshall Stability and Flow of Bituminous Mixtures, Copyright © ASTM International

ASTM D4123-82, Standard Test Method for Indirect Tension Test for Resilient Modulus of Bituminous Mixtures, Copyright © ASTM International

Hamzah, M. O., Hassan, M. R., and Ven, M. (2010) - *Permeability Loss in Porous Asphalt Due To Binder Creep*, Journal of Construction and Building Materials 30 (2012) 10–15

Hanim, F. and Jazlina (2008) *–Design of Porous Asphalt Mixture to Performance Related Criteria*, Public Works Department (JKR), Malaysia

Harris, C. H., Wang, L., Flintsch, G., Filz, G. (2007) *–Hot Mix Asphalt Permeability: Tester Size Effects and Anisotropy*, Blacksburg

Hardiman, M.O. Hamzah, A.A. Mohammed (2004) -*Binder Drainage Test For Porous Mixtures Made By Varying The Maximum Aggregate Sizes,* School of Civil Engineering, Universiti Sains Malaysia (USM).

Incegull, M. and Ergun, M. (2011) – *An Integrated Graphical User Interface For Pavement Deterioration Modeling*, ISSN 1992-2248 ©2011 Academic Journals, Scientific Research and Essays Vol. 6(17), pp. 3649-3656, 26 August, 2011

Kandhal, P. S. and Mallick R. B. (1999) –Design of New-Generation Open-Graded Friction, NCAT Report No. 99-3

Krishnan, J. M., and Rao, C. L. (2000) - *Permeability and Bleeding Of Asphalt Concrete Using Mixture Theory*, International Journal of Engineering Science 39 (2001) 611-627

Lira, B., Jelagin, D., and Birgission, B. (2011) - *Gradation-Based Framework For Asphalt Mixture,* Journal Materials and Structures (2013) 46:1401–1414

Mansour, T. N. and Putman, B. J. (2013) - *Influence of Aggregate Gradation on the Performance Properties of Porous Asphalt Mixture*, Journal Of Materials In Civil Engineering, ASCE , February 2013

Mathew, T. V. and Rao, K. (2006) - *Chapter 26 = Marshall Mix Design, Introduction to Transportation Engineering*, NPTEL May 24, 2006

McDaniel, R. S. (2008) –*Safe, Quiet and Durable Highway*, Rocky Mountain Asphalt Conference, February 21, 2008

Mokhtar, M. (2006) –The Effect of Drain Asphalt Modified Additive (DAMA) on the Engineering Properties and Performance of Porous Asphalt, Master Thesis

Neptune, A. I., and Putman, B. J. (2010) - *Effect of Aggregate Size and Gradation on Pervious Concrete Mixtures*, ACI Materials Journal/November-December 2010

Nursetiawan, Woodward, D. and Strong, A. (2008) – *Predicting the Effect of Rainfall on Asphalt Surfacing Materials,* Highway Engineering Research Group, University of Ulster, Jordanstown BT37 0QB, Northern Ireland

Park, T. (2007) - *Causes Of Bleeding In a Hot-In-Place Asphalt Pavement*, Construction and Building Materials 21 (2007) 2023–2030

Pei, J., Chang, M., and Zhang, J. (2011) - *Optimal Air Void for Strength and Permeability of Porous Asphalt Mixture Based on Topological Optimization*, Journal ASCE 2011

Poulikakos L. D., Gubler, R., Partl, M., Pittet, M., Arnaud, L., Junod, A., and Dumont, A. (2006) –*Mechanical Properties of Porous Asphalt*, Swiss Federal Laboratory for Materials Testing and Research, Empa, Dubendorf, Switzerland

Singh, A., Das, A. and Basu, S. (2010) - *A Numerical Study on the Effect of Aggregate Gradation on Mechanical Response of Asphalt Mix*, KSCE Journal of Civil Engineering (2012) 16(4):594-600

Sivan B. S. and Mathew B. S. (2009) – *Effect of Gradation of Aggregates on the Properties of Stone Matrix Asphalt*, College of Engg. Trivandrum

Tarmuzi, N. A. (2013) - *The Effect Of Aggregate's Angularity On Engineering Properties And Performance Of Porous Asphalt*, Master Thesis of Universiti Teknologi Malaysia

Vivar, E. P. and Haddock, J. E. (2006) - *HMA Pavement Performance and Durability*, Publication FHWA/IN/JTRP-2005/14., Joint Transportation Research Program, Indiana Department of Transportation and Purdue University, West Lafayette, Indiana, 2006.

Williams, S. G. (2006)–*A Comprehensive Study Of Field Permeability Using The Vacuum Permeameter, Department of Civil Engineering*, University of Arkansas

Xiaoping, Y., Xuan, W., and Yi, Y. (2011) - Relationship between Void Feature and Road Performance of Porous Asphalt Mixture Based On Image, Journal ASCE 2011

Zhao, H., Sun, W., Wo, X., and Gao, B. (2012) - *The Effect Of Coarse Aggregate Gradation On The Properties Of Self-Compacting Concrete Technique*, Journal of Materials and Design 40 (2012) 109–116

AUSTROADS (1999) - Air Voids in Asphalt, Pavement Work Tips No. 17, Australian Asphalt Pavement Association, June 1999

Institute for Road Safety Research (2012) – *The Influence Of Weather On Road Safety, Institute for Road Safety Research*, © SWOV, Leidschendam, the Netherlands February 2012

Malaysian Metrological Department (2012), official website at www.met.gov.my

Standard Specification for Road Work, Section 4: Flexible Pavement, Jabatan Kerja Raya (JKR) Malaysia, 2008

U.S. Environmental Protection Agency (2009) –*National Pollutant Discharge Elimination System (NPDES)*, online available at cfpub.epa.gov/

National Technical Information Service (1971) - U. S. Army Test and Evaluation Command, Common Engineering Test Procedure, Creep Test Procedures, .31 January 1968

Buchanan, S. (2007) – Resilient Modulus-What, Why and How? Vulcan Material Company

Yalcinkaya, C., -Dokuz Eylul Universitesi, available online at http://www.caglaryalcinkaya.com/FileUpload/ks149954/File/porous_asphalt.pdf

austroads.com (2005), available online at http://www.austroads.com.au/images/stories/T236_Particle_loss.pdf

www.pavegreen.com

chesapeakestormwater.net

Roadstone Dublin Ltd Publication

www.pavementinteractive.org

www.uotechnology.edu

www.wolfpaving.com

www.in.gov

www.geotechdata.info

www.labs4u-construction.co.uk

www.msed.nist.gov