UNIVERSITI PUTRA MALAYSIA

DEVELOPMENT OF HYDROPAVE ASPHALT MIXTURE FOR MALAYSIAN ROADS

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By

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Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfilment of the Requirements for the Degree of Master of Science

October 2014

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of requirement for the degree of Master of Science

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October 2014

Chair: Professor Ratnasamy Muniandy, PhD
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Wet condition roads has been one of the contributing factor of accidents, this is especially critical for countries such as Malaysia that receives rain all year round. The decrease on friction resistance, increase possibility of hydroplaning and reduce of sight visibility due to splashing ultimately increases the hazard of road users. In order to mitigate this problem, porous asphalt was introduced in Malaysia. The term porous asphalt represents high amount of air voids or percentage of voids in total mix (VTM) which was designed to drain off excessive runoff from pavement surface during storm. However, the application of porous asphalt is not very popular in Malaysia due to its costly mixed necessary to achieve required water drainage at the expense of higher ratio of coarse aggregates and lower binder viscosity. Thus, Hydropave asphalt mixture is developed in this study to overcome the said problem by implementing an effective drainage on road pavement. This technique is achieved by categorizing rainfall depths into different zones and by proposing a suitable cross fall as well as required air voids content in asphalt mixtures. Based on the Malaysia annual rainfall data for year 2000 to 2009, three different zones were categorized ranging from high to low. In order to achieve the optimum efficiency in terms of performance and cost for Hydropave asphalt mixture, the recommended VTM and cross fall established is then assigned to each zone. Laboratory experiments which included rainfall simulation on hydropave mixture slabs at different design VTM was conducted to obtain the relationship of variables in this study. Five hyropave asphalt slabs were designed based on five different air voids at 10%, 15%, 20%, 25% and 30%. Results for high rainfall zone found that the VTM required were from 20% to 23% as recommended cross fall for a maximum of 6% to a minimum of 2.5% inclination respectively in order to sufficiently drainoff the surface runoff. During moderate rainfall intensity, the required air voids to eliminate water ponding condition was lower when compared to high rainfall intensity zone which was 18% to 20% with corresponding flow rate of 230.3 to 389.5 cm^3/s when applied on minimal cross slope of 2.5%, while asphalt mixture slab containing lower percentage of air voids at 14% to 18% would be sufficient when cross slopes of 3.0% to 6.0% is allowed. For lowest rainfall intensity zone, results shown that asphalt mixtures with air voids contents ranging 14% to 18% has no water ponding condition with fulfilling minimal cross slope requirement at 2.5% during rainfall simulation test.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Master Sains

PEMBANGUNAN TURAPAN HYDROPAVE UNTUK JALAN RAYA DI MALAYSIA

Oleh

CHUAH POOI YEE

Oktober 2014

Pengerusi: Professor Ratnasamy Muniandy, PhD
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Malaysia adalah sebuah negara yang mempunyai kadar purata hujan yang tinggi sepanjang tahun. Fenomena ini adalah salah satu faktor penyumbang utama kepada statistik kemalangan jalan raya. Keadaan jalan basah mengurangkan rintangan geseran, meningkatkan geluncuran dan pengurangan kebolehan penglihatan akibat daripada percikan air. Demi mengatasi masalah ini, penggunaan *porous asphalt* telah diperkenalkan di Malaysia. Terma *porous asphalt* adalah mewakili turapan yang mengandungi kuantiti lompang udara yang tinggi di mana ia direkabentuk untuk menghapuskan larian permukaan yang ketara semasa hujan. Walaubagaimanapun, penggunaan *porous asphalt* tidak popular di Malaysia kerana kosnya yang mahal lanjutan daripada nisbah saiz agregat kasar kekuatan kelikatan bitumen yang tinggi. Oleh itu, turapan hydropave telah dibangunkan bagi mengatasi permasalahan tersebut. Kaedah ini dicapai melalui pengkategorian kedalaman hujan kepada beberapa zon yang berbeza dan mencadangkan kecondongan yang bersesuaian serta lompang udara yang diperlukan dalam campuran turapan. Berdasarkan purata hujan tahunan sepanjang tahun 2000 sehingga 2009, sebanyak tiga zon telah dikategorikan pada lingkungan tinggi ke rendah. Bagi mencapai keberkesanan optimal dari segi keupayaan dan kos, teknologi campuran hydropave disarankan peratus VTM dan kecondongan yang telah dicadangkan bagi setiap zon. Lima keratan turapan hydropave telah disediakan berdasarkan rekabentuk lompang udara 10%, 15%, 20%, 25% dan 30%. Experimen di makmal termasuk simulasi hujan ke atas keratan turapan hydropave pada VTM rekabentuk yang berbeza dijalankan bagi mendapatkan hubungankait pembolehubah di dalam kajian ini. Keputusan menunjukkan zon kekerapan hujan tinggi mendapati kandungan lompang udara antara 20% hingga 23% adalah diperlukan dengan kecondongan antara 6.0% hingga 2.5% bagi mengatasi larian permukaan. Ketika hujan sederhana, keperluan lompang udara bagi menghapuskan keadaan air bertakung adalah lebih rendah berbanding ketika hujan lebat iaitu 18% hingga 20% dengan kadar alir 230.3 cm^3/s hingga 484.6 cm^3/s pada kecondongan minimum manakala bagi keratan turapan yang mengandungi peratusan kandungan udara lebih rendah pada 14% hingga 18% memadai apabila kecondongan 3.0% hingga 6.0% adalah dibenarkan. Bagi zon hujan rendah didapati kandungan udara di antara 14% hingga 18% tidak mengalami takungan air dengan kecondongan minimal 2.5%. semasa ujian simulasi hujan.

ACKNOWLEDGEMENTS

I would like this begin this with the dedication of my thankfulness to the Almighty. In His mercy, I am able to overcome any obstacles thrown in my way of completing this report. I would also like to express my utmost gratitude to my supervisor, Professor Dr. Ratnasamy Muniandy and another member of supervisory committee, Associate Professor Ir Salihudin Hassim for their sincere advice, guidance and never-ending support throughout the course of this research. Their kindness and encouragement have played a big part in giving me the strength to complete this report until the very end.

I also want to acknowledge Department of Civil Engineering, Universiti Putra Malaysia for providing me the facilities and support needed to conduct this research. All colleagues and friends' involvement in this project and their helping hands are truly appreciated. The contributions and information sharing of Malaysian Department of Irrigation and Drainage and Public Works Department have also been a big part of the success of this research.

Special thanks to my family for all unlimited supports and patience that empower me to go further in learning and experiencing different stages of life.

I certify that a Thesis Examination Committee has met on 2 October 2014 to conduct the final examination of Chuah Pooi Yee on the thesis entitled "Development of Hydropave Asphalt Mixture for Malaysian Roads" in accordance with the Universities and University Colleges Act 1971 and the Constitution of the University Putra Malaysia [P.U.(A) 106] 15 March 1998. The Committee recommends that the student be awarded the Master of Science.

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INTRODUCTION

1.1 Background of Study

Malaysia is a tropical climate country with high temperatures and rainfall throughout the year. The different altitude and exposure of coastal lowlands to alternating northeast and southeast monsoon winds give seasonal rainfall in Peninsular Malaysia, as well as Sabah and Sarawak in Malaysia. Southeast Monsoon occurs from November to February while Northeast Monsoon occurs from April to September. March and October are the transition months between the monsoons, which will experience unpredictable winds. Rainfall in Malaysia occurs almost everywhere throughout the year and falls on 150 to 200 days of the year.

Rainfall condition in Malaysia has caused different driving condition on the roads as during dry road condition, therefore porous asphalt mixture was brought-in. Porous asphalt has been applied in Malaysia though it is not popular due to expensive costing compared to conventional mixture. According to Hardiman, et. al., the first porous asphalt trial in Malaysia was at the Cheras-Berang Road. Some other places that applied porous pavement include short span of North-South Highway, Jalan Tebrau, Johor Bahru, small part of Federal Highway (has reached its design life) and the latest along Kerinchi Link. Each application has its objectives to meet in order to resolve certain issue which conventional pavement could not be achieved (Hardiman, et al., 2004). In this study, hydropave asphalt mixture is introduced as a type of porous asphalt which has more different ranges of air voids assigned specifically to areas in Malaysia.

1.2 Problem Statement

Rainfall has contributed to the damages on road in Malaysia where large amount of allocations were distributed by Malaysian Ministry of Work for road rectification after season of heavy rainfall. Based on the information obtained from Malaysian Public Works Department, government has spent RM 140 million in year 2009 to repair road damages caused by heavy rainfall in year 2008. As for the following year 2010, the amount spent reduced to RM 38.7 million. However, the amount spent increased to RM 120 million in year 2011. The severity of cost consumption has indicated that Malaysian Government has to spend hundreds of millions solely on the purpose to repair road damages caused by rainfall.

Besides that, rainfall affects the road environment in many ways. First, there result a reduction in friction between the vehicle tires contact with the road surface during wet conditions, resulting in the need for a greater stopping distance; and second, visibility can be severely limited during rain. Not only the view through the windscreen is hindered, but the splashing and spraying of water stagnant on the road surface by other vehicles create additional visibility problems. Notwithstanding these effects, people hardly cancelled or delayed their journeys because of wet weather (K.Smith, 1982).

There was more that 25% of road accident in United Kingdom during wet condition of road surface is caused by skidding. From their study, a certain level of improvement in skid resistant of the wearing coarse resulted decrement in accident rate during wet condition (Panagouli, et al., 1998). By referring to the information provided by Malaysian Public Works Department, as presented in Figure 1.1, it shows that road accidents during wet surface condition took up 13.25% of total road accidents in year 2010, the second highest after dry normal surface condition.

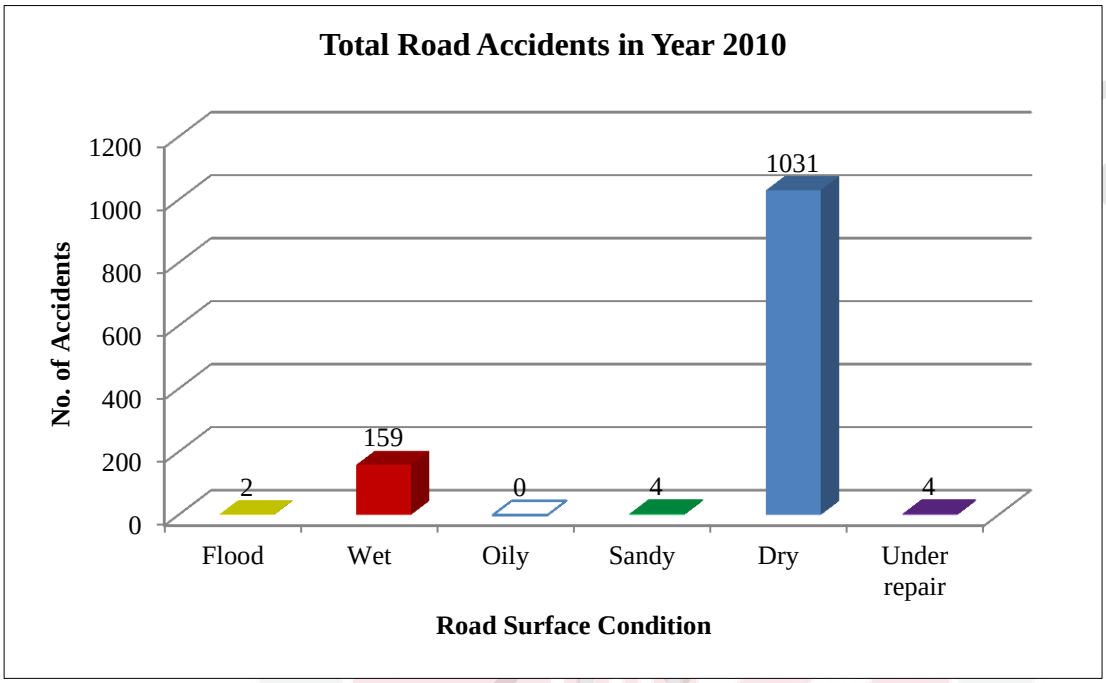

Figure 1.1 Total Road Accidents in Malaysia in 2010.
Source: (Public Works Deparment Malaysia, 2008)

Road accidents may easily happen when the skid resistance is insufficient. Skid resistance besides contributing to road safety factor, it is also one of the key components in order to measure the performance and serviceability of pavement in term of life-cycle costs. The micro-texture of road surface dominates an efficiency of skid resistance and an adhesion component predominates, this happened when vehicle travels up to certain speed. In conventional HMA (Hot Mix Asphalt), an increasing speed of vehicles goes linearly with the difficulty level of the pavement surface to penetrate water in film within the time available. This is one of the reasons which brought technology of open-graded friction course or more commonly known as porous asphalt in Malaysia.

However, this application of porous asphalt is not very popular in Malaysia. It is a costly mixes due to the high percentage of course aggregates requires for lower viscosity binder. According to Ir. Zulakmal B. Sufian (Special Officer Public Work Director, JKR, 2009), the cost of normal hot mix asphalt is approximately RM 10 per square meter whereas the cost for porous asphalt is RM 22 per square meter. Cost is one of the main factors which cause the lack of favor in application in many areas in Malaysia.

Rainfall zoning is essential in Malaysia to develop a cost effective open-graded asphalt mixture, which termed as Hydropave, as it is design as open-graded asphalt mixture that suit according to the needs of an area. With the rainfall zoning based on the requirement for porous asphalt, overdesign of air voids could be avoided, as higher voids content leads to lower strength in porous asphalt mixture, whereby the zoning also can be a guide to identify critical areas as well as unnecessary areas and costs to be spent.

1.3 Objectives

1. To develop rainfall zones for Malaysia based on Meteorological data.
2. To design porous asphalt mixtures with various percentage of air voids
3. To establish air voids-flow characteristics for Hydropave asphalt mixture

1.4 Scope of study

This study is conducted to develop a rainfall zoning map with the approach of open-graded mixture based on the zone necessities. The data obtained from Malaysian Department of Irrigation and Drainage of the past ten years would be analyzed to determine the rainfall pattern. Based on the rainfall zoning map, areas that have the necessities of hydropave asphalt mixture application is then identified, as well as areas that suitable with application of conventional mixture.

Hydropave asphalt mixture slabs are designed at different air voids content ranging between 10% to 30% to determine the drainage capacity. Design of hydropave asphalt mixture is mainly focus to achieve the air voids content for drainage performance while it is not a strength based design. Rainfall simulation is conducted with different rainfall intensities to determine water film thickness on hydropave asphalt mixture slabs using the available rainfall simulator in UPM's laboratory and water depth gauge. A commercially available laboratory drainability tester (permeameter) is used to measure the flow rate of water through specific voids content of hydropave. Hydropave is designed on few ranges of air void and performance test is conducted to evaluate its reliability. Though one of the issues mentioned regarding usage of hydropave mixture related to cost effectiveness, however it is not covered in this study since it has to collaborate with strength required. Simple cost comparison is discussed in later part of this study.

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