



UNIVERSITI PUTRA MALAYSIA

***DEVELOPMENT OF HYDROPAVE ASPHALT MIXTURE
FOR MALAYSIAN ROADS***

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**DEVELOPMENT OF HYDROPAVE ASPHALT MIXTURE FOR
MALAYSIAN ROADS**

By

CHUAH POOI YEE

**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

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

DEVELOPMENT OF HYDROPAVE ASPHALT MIXTURE FOR MALAYSIAN ROADS

By

CHUAH POOI YEE

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 cm³/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

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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 lompong 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 lompong 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 lompong udara 10%, 15%, 20%, 25% dan 30%. Eksperimen 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 lompong udara antara 20% hingga 23% adalah diperlukan dengan kecondongan antara 6.0% hingga 2.5% bagi mengatasi larian permukaan. Ketika hujan sederhana, keperluan lompong udara bagi menghapuskan keadaan air bertakung adalah lebih rendah berbanding ketika hujan lebat iaitu 18% hingga 20% dengan kadar alir 230.3 cm³/s hingga 484.6 cm³/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.

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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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TABLE OF CONTENTS

	Page
ABSTRACT	i
ABSTRAK	ii
ACKNOWLEDGEMENTS	iii
APPROVAL	iv
DECLARATION	vi
LIST OF TABLES	xi
LIST OF FIGURES	xiii
CHAPTER	
1 INTRODUCTION	1
1.1 Background of Study	1
1.2 Problem Statement	1
1.3 Objectives	3
1.4 Scope of study	3
2 LITERATURE REVIEW	4
2.1 Rainfall Distribution in Malaysia	4
2.1.1 Seasonal Rainfall Variation in Malaysia	4
2.1.2 Climate Change Scenario in Malaysia	5
Rainfall Measurement	6
2.1.3 Average Rainfall over an Area	7
2.1.4 Rational Method	9
2.1.5 Computer Mapping Methods for Rainfall Intensity	10
2.2 Type of Asphalt Mixture	11
2.2.1 Dense-Graded Mixtures	11
2.2.2 Gap-Graded Mixtures	11
2.2.3 Open-Graded Mixtures	12
2.3 Importance of Road Drainage	13
2.3.1 Surface Drainage	13
2.3.2 Subsurface Drainage	14
2.4 Requirement of Cross Slope in Road Geometric Design	15
2.5 Effect of Hydroplaning	15
2.5.1 Causes	15
2.5.2 Water film Thickness	16
2.6 Application of Porous Asphalt	18
2.6.1 Properties of Modified Binder	20
2.6.2 Gradation Theory for Porous Asphalt Mixture	21
2.6.3 Permeability	24
2.6.4 Measurement of Permeability	25
2.6.5 Application of Rainfall Simulator	27
2.7 Asphalt Mixtures Design	27
2.8 Advantages and Disadvantages of Porous Asphalt	30
2.8.1 Advantages	30
2.8.2 Disadvantages	34
2.9 Summary of Literature Review	36

3	METHODOLOGY	37
3.1	Introduction	37
3.2	Rainfall Zoning	41
3.3	Material Characterization	41
3.3.1	Grading Selection	41
3.3.2	Specific Gravity Test for Aggregates	42
3.3.3	Aggregate Los Angeles Abrasion Test	42
3.3.4	Aggregate Flakiness Test	42
3.3.5	Aggregate Soundness Test	42
3.3.6	Asphalt Penetration Test	42
3.3.7	Asphalt Viscosity Test	43
3.3.8	Asphalt Flash and Fire Point Test	43
3.3.9	Asphalt Softening Point Test	43
3.4	Design of Porous Asphalt Mixtures	44
3.4.1	Rice Specific Gravity/Theoretical Maximum Density (TMD)	44
3.4.2	Specimen Preparation and Compaction for Design Binder Content	45
3.4.3	Determination of Design Binder Content	47
3.5	Preparation of Asphalt Mix Slab Using Turamesin	47
3.5.1	Mixing	48
3.5.2	Compacting	49
3.6	Performance Analysis	51
3.6.1	Cross slope Configuration	51
3.6.2	Water Film Thickness Measurement	52
3.6.3	Drainability Test	55
3.6.4	Density Measurement	56
3.6.5	Voids in Total Mix	56
3.6.6	Voids – Flow Analysis	57
3.6.7	Analysis of Variance (ANOVA)	57
4	RESULTS AND DISCUSSION	58
4.1	Introduction	58
4.2	Rainfall Data Collection	58
4.2.1	Rainfall Zoning	62
4.2.2	Hydropave Zone	65
4.2.3	Rainfall Intensity Calculation using Rational Method	69
4.3	Material Characterization	70
4.3.1	Aggregate Gradation	70
4.3.2	Specific Gravity of Aggregates	71
4.3.3	Aggregate Los Angeles Abrasion Test	72
4.3.4	Aggregate Flakiness Index	72
4.3.5	Aggregate Soundness Test	73
4.3.6	Asphalt Penetration Test	73
4.3.7	Asphalt Softening Point Test	74
4.3.8	Asphalt Viscosity Test	74
4.3.9	Asphalt Flash point	75
4.3.10	Summarized Results for Material Characterization	75
4.4	Design of Hydropave Asphalt Mixtures	76

4.4.1	Theoretical Maximum Specific Gravity (G_{mm})	77
4.4.2	Design Binder Content	79
4.4.3	Mass of Mixtures for Turamesin Slabs	85
4.4.4	Aggregates Mass Calculation	86
4.5	Performance Analysis	86
4.5.1	Determination of Pavement Cross Slope	87
4.5.2	Air Voids – Flow Analysis	88
4.5.3	Performance in Drainability	91
4.5.4	Analysis of Variance (ANOVA)	94
4.5.5	Density Properties	95
4.5.6	Estimated VTM (%) and the Measured VTM (%)	99
4.6	Results of Hydropave Zone with Air Voids Recommendation	100
4.6.1	Comparison in Cost Estimation for Asphalt Mixtures at different air voids range	103
5	CONCLUSION AND RECOMMENDATIONS	106
5.1	Conclusion	106
5.2	Recommendations	107
5.3	Thesis Contribution	108
	REFERENCES	109
	APPENDICES	117
	BIODATA OF STUDENT	135

LIST OF TABLES

Table	Page	
2.1	Type of rain in term of intensity	6
2.2	Runoff Coefficient, C	10
2.3	Average values of porosity, permeability and Marshall stability for various gradations	22
2.4	Gradation Limits of Combined Aggregates	23
2.5	Effects of porous asphalt on risk factors associated with accident occurrence	32
2.6	Different surface types' acoustic absorption characteristics	34
3.1	Gradation Limits of Combined Aggregates	41
3.2	Requirement of Material Properties in Porous Asphalt Mixtures by Public Works Department, Malaysia	44
4.1	Number of rainfall stations in every state in Malaysia	59
4.2	Average rainfall intensity in Perlis (year 2000 – 2009)	61
4.3	Average Annual Rainfall in Malaysia (2000 – 2009)	62
4.4	Boundary of average rainfall intensity at each zone	63
4.5	Range of rainfall intensity for each zone	63
4.6	Hydropave zones involving different states and areas in Malaysia	68
4.7	Gradation for porous mix	70
4.8	Specific Gravity of Aggregates and Percent of Absorption	72
4.9	L.A. Abrasion Loss	72
4.10	Flakiness Index of Coarse Aggregates	73
4.11	Soundness test results	73
4.12	Penetration Test	74
4.13	Softening Point Result	74
4.14	Summary of Results on Tests Conducted on Aggregate and Asphalt Samples	76
4.15	Results of Theoretical Maximum Specific Gravity from Rice Method	78
4.16	Calculated Theoretical Maximum Specific Gravity based on through Rice Method	78
4.17	Mass calculation for 20% of air voids sample	79
4.18	Summary of Results for Optimum Asphalt Content (OAC) based on Modified Asphalt Institute Method	81
4.19	Results of Samples Mix Properties (Design Binder Content)	83
4.20	Properties of porous asphalt mix at Design Binder Content	85
4.21	Mass of material for each slab at designed air voids	86
4.22	Aggregate mass by fractions for porous asphalt mixture	86
4.23	Summary of the height requirement that needed to achieve the cross fall percentage	87
4.24	Results of Water Film Thickness (WFT) measured at 12 cross slopes at 3 different rainfall intensities with 5 porous asphalt slabs	88
4.25	Minimum Slope Requirement	90
4.26	Results of Drainability Tests	93

4.27	Rate of change in flow rate against percent of air voids for different porous asphalt mixture slabs	93
4.28	Effect of Air Voids Content on Flow Rate	
4.29	Summary of ANOVA: single factor	94
4.30	Result of ANOVA	94
4.31	Density and Volumetric Properties of Samples	97
4.32	Hydropave zones with recommended air voids at corresponding cross slopes	101
4.33	Hydropave zones with recommended air voids at corresponding cross slopes	102
4.34	Hydropave zones with recommended air voids at corresponding cross slopes	103
4.35	Price of bitumen in Malaysia (January, 2013)	103
4.36	Estimation for cost comparison between different asphalt types at different air voids content	105
A1	Annual Rainfall Data in Malaysia (2000 – 2009)	117
B1	Hydropave zones involving different states and areas in Malaysia	129
B2	Hydropave Zone I with recommended air voids at corresponding cross slopes	132
B3	Hydropave Zone II with recommended air voids at corresponding cross slopes	133
B4	Hydropave Zone III with recommended air voids at corresponding cross slopes	134

LIST OF FIGURES

Figure		Page
1.1	Total Road Accidents in Malaysia in 2010	2
2.1	Comparison of Annual Rainfall Change (%) for the Period 2000 – 2007 relative to The Period 1990-1999), based on the MMD's Surface Observation Stations Data	6
2.2	Hypothetical catchment with one gauging station and associated Thiessen polygon defined	8
2.3	Isohyetals of a rainfall	9
2.4	Load cycles to failure vs. asphalt blend for various temperatures	12
2.5	Surface texture	13
2.6	Water Film Depth vs Rainfall Intensity	17
2.7	Water film thickness vs flow path slope	17
2.8	Water film thickness vs surface texture depth	18
2.9	Percentage of air voids against 2 different gradations and binder type	23
2.10	Relation between connective void and permeability coefficient	25
2.11	Head versus flow rate data for in situ tests	26
2.12	Difference in spray from conventional and PFC pavements	33
3.1	Flow Chart of Research Methodology	38
3.2	Experimental Design	39
3.3	Gyratory Compactor used to prepares porous mix samples	46
3.4	Mix Samples; three samples with similar binder content for five different binder content	47
3.5	Mixing Apparatus	49
3.6	Turamesin Roller Compactor	50
3.7	Finished product of porous sample	51
3.8	Basic Rainfall Simulator	52
3.9	Slab holder	53
3.10	Sprinkler and upvc pipe setting	54
3.11	Water film built up during rainfall intensity test	55
4.1	Raw rainfall data in Station Padang Katong at Kangar, Perlis	60
4.2	Raw rainfall data in Station Ngolang at Perlis	60
4.3	Average Annual Rainfall in Malaysia (year 2000-2009)	61
4.4	Malaysia map entered in ArcGIS	63
4.5	Input of data locations consisting coordinates of longitude, latitude and rainfall data of each station	64
4.6	Selection of method based on geometric interval into 3 classes	64
4.7	Map of color zones divided to 3 rainfall zones	65
4.8	Average Annual Rainfall of Peninsular Malaysia (mm), year 2000 – 2009	66
4.9	Average Annual Rainfall of Sabah and Sarawak (mm), year 2000 – 2009	67
4.10	IDF curve based on station 10 years return period	69
4.11	Envelope of aggregate gradation for porous asphalt mixture	71
4.12	Viscosity versus Temperature	75

4.13	Bulk Density vs. Asphalt Content	81
4.14	VTM vs. Asphalt Content	81
4.15	Marshall Stability vs. Asphalt Content	82
4.16	Marshall Stability against Asphalt Content	84
4.17	Bulk Specific Gravity against Asphalt Content	84
4.18	VTM % against Asphalt Content	84
4.19	Resilient Modulus against Asphalt Content	84
4.20	VMA % against Asphalt Content	84
4.21	VFA % against Asphalt Content	84
4.22	Water film thickness against various slopes at low rainfall intensity zone	89
4.23	Water film thickness against various slopes at medium rainfall intensity zone	90
4.24	Water film thickness against various slopes at high rainfall intensity zone	90
4.25	Permeability against percentage of air voids	92
4.26	Flow rate against percentage of air voids	92
4.27	Voids in Total Mix, VTM (%) against Specific Gravity of Slabs	96
4.28	Voids Properties of Slab 1	98
4.29	Voids Properties of Slab 2	98
4.30	Voids Properties of Slab 3	98
4.31	Voids Properties of Slab 4	98
4.32	Voids Properties of Slab 5	98
4.33	Voids Properties of Slab 6	98
4.34	Comparison between measured VTM and the target VTM	99
B1	Average Annual Rainfall in Malaysia (year 2000-2009)	128
B2	Average Annual Rainfall of Peninsular Malaysia (mm), year 2000 – 2009	130
B3	Average Annual Rainfall of Sabah and Sarawak (mm), year 2000 – 2009	131
B4	Flow rate against percentage of air voids	134

CHAPTER 1

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 than 25% of road accidents 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 course resulted in a 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.

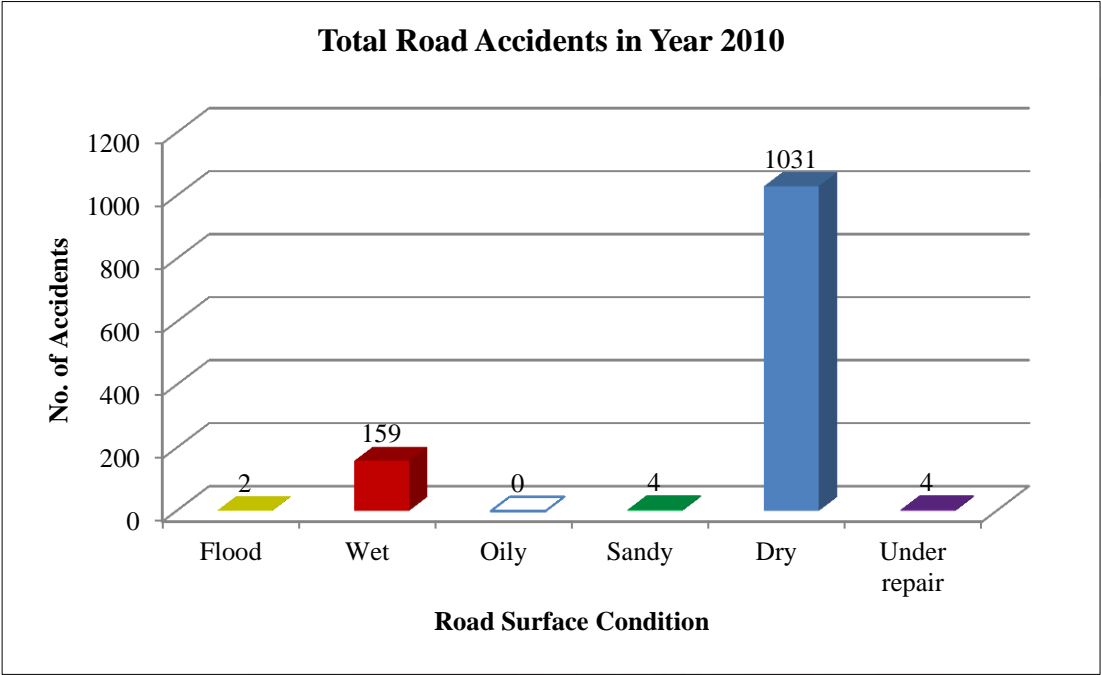


Figure 1.1 Total Road Accidents in Malaysia in 2010.
Source: (Public Works Department Malaysia, 2008)

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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