

**EVALUATION OF LABORATORY COMPACTIVE EFFORT ON
ASPHALTIC CONCRETE MIXES**

NUR SABAHAH BINTI ABDUL SUKOR

UNIVERSITI TEKNOLOGI MALAYSIA

**EVALUATION OF LABORATORY COMPACTIVE EFFORT ON
ASPHALTIC CONCRETE MIXES**

NUR SABAHAH BINTI ABDUL SUKOR

A thesis is submitted in fulfillment of the requirements for the award of the degree of
Master of Engineering (Civil- Highway and Transportation)

**Faculty of Civil Engineering
University Technology of Malaysia**

MARCH, 2005

*This is tough,
But,
The quitter never wins,
And,
The winner never quits.*

ACKNOWLEDGEMENT

In the name of ALLAH, the Bountiful and the Merciful. Praise be upon Him, with His grace extends my existence to pen down my gratitude to whom I am going to mention in these following paragraphs.

First and foremost, I wish to thank my caring and guiding supervisor **Dr. Mohd Rosli Bin Hainin** to support me in many ways. Besides, to all staffs of Highway and Transportation Laboratory, UTM: **En. Abdul Rahman, En. Suhaimi, En. Azman and En. Ahmad Adin**, for helping me in many tasks along my way to finish this dissertation. Not forget to **En. Che'Ros Bin Ismail** with all his advices.

My gratitude also goes to all staffs of Highway and Transportation Laboratory, KUiTTHO for always supporting me and guiding my works. Especially to my kind-hearted colleague **Nizam** who was always available to help me.

For **mom and dad**, who are always being my inspiration, I love both of you most. My fellow friends at Level 4 K13 and my 'soul mate' **Nana**, thank you for cherishing my life. I would like to take the opportunity to ask forgiveness on any ill manner. Shortcomings and mistakes are inevitable of us as human being. Only ALLAH may repay the help given to me by all of you.

Wassalam.

ABSTRAK

Kaedah pemadatan yang betul merupakan faktor utama di dalam kerja-kerja penurapan jalan di makmal atau di tapak. Mampatan yang tinggi menghasilkan turapan jalan yang lebih padat. Rekabentuk Campuran Marshall menggariskan 75 hentakan sebagai nilai pemadatan yang digunakan di dalam kerja makmal. Masalah timbul apabila pemadatan yang terlalu tinggi ini menyebabkan pengurangan terhadap ketahanan turapan jalan tersebut. Tujuan kajian ini lebih menjurus kepada mengenal pasti kebolehan 50 hentakan berbanding dengan 75 hentakan yang biasa digunakan di dalam Rekabentuk Campuran Marshall. Kajian ini melibatkan ujikaji terhadap dua jenis campuran asphalt iaitu ACW 20 dan ACW 14. Kedua-dua campuran dibahagikan kepada 2 jenis hentakan iaitu 50 dan 75 hentakan. Campuran ACW 20 diuji dengan menggunakan prosedur AASHTO T283-89 manakala campuran ACW 14 diuji berdasarkan prosedur ASTM D4123. Hasil ujikaji bagi ACW 20 menunjukkan bahawa 50 hentakan memberikan nilai kekuatan tegangan yang lebih tinggi berbanding dengan 75 hentakan. Ujikaji bagi ACW 14 pula menunjukkan bahawa 75 hentakan memberikan nilai modulus kekenyalan yang lebih tinggi berbanding 50 hentakan. Akan tetapi, modulus kekenyalan bagi campuran yang menggunakan 50 hentakan masih memenuhi piawaian. Secara keseluruhannya, campuran yang menggunakan 50 hentakan mempunyai kebolehtahanan yang sama dengan campuran yang menggunakan 75 hentakan sebagai daya pemadatan.

ABSTRACT

Good compaction is the most important factor to consider when constructing asphalt mix ture either in the laboratory or in the field. The higher compactive effort presents the higher density to the pavement. The 75 blows as compactive effort in designing laboratory Marshall mix es sample is usually selected. Too high compaction could affect the pavement durability. The aim of this study is to investigate the performance of 50 blows comparing to 75 blows of compactive effort in Marshall Mix Design. The experiment included two types of mix es, ACW14 and ACW20 where 50 and 75 blows were used for each mix . ACW20 samples were tested according to AASHTO T283-89 "Resistance of Compacted Bituminous Mix ture to Moisture Induced Damage" and ACW14 samples were tested using Universal Testing Machine according to ASTM D4123 "Standard Test Method for Indirect Tension Test for Resilient Modulus of Bituminous Mix tures." 50 blows compactive effort for ACW20 showed the higher tensile strength ratio when tested for moisture induced damage. For ACW14, the 50 blows compactive effort indicated lower Resilient Modulus than the 75 blows but still above the estimated performance. In general, mix es with 50 blows compactive effort indicated the same performance with the 75 blows samples.

TABLE OF CONTENTS

CHAPTER	TOPIC	PAGE
	TOPIC	i
	DECLARATION	ii
	DEDICATION	iii
	ACKNOWLEDGEMENTS	iv
	ABSTRACT	v
	AB STRAK	vi
	TABLE OF CONTENTS	vii
	LIST OF TABLES	ix
	LIST OF FIGURES	x i
	LIST OF APPENDICES	x iii
1	INTRODUCTION	1
	1.1 Problem statement	2
	1.2 Objectives	4
	1.3 Scope of study	4
	1.4 Purpose of study	4
	1.5 Marshall Mix Design Method	5
2	LITERATURE REVIEW	6
	2.1 Introduction	6
	2.2 Effect of Compaction	9
	2.3 Asphalt Film Thickness	19.
	2.4 Relient Modulus	23
	2.5 Field Performance	25

3	METHODOLOGY	26
3.1	Introduction	26
3.2	Laboratory Test Procedure	28
3.3	Aggregate preparation	29
3.4	Marshall Mix Design	30
3.4.1	Mix Design preparation	31
3.5	Marshall Tests	36
3.5.1	Bulk Specific Gravity of Compacted Bituminous Mixtures Using Saturated Surface-Dry Specimens (ASTHO T166-88)	36
3.5.2	Resistance to Plastic Flow of Bituminous Mixtures Using Marshall Apparatus (ASTHO T245-90)	38
3.5.3	Resistance of Compacted Bituminous Mixture to Moisture Induced Damage (AASHTO T283).	40
3.5.4	Standard Test Method for Indirect Tension Test for Resilient Modulus of Bituminous Mixture (ASTM D 4123) by using Universal Testing Machine	44
4	RESULTS AND ANALYSIS DATA	47
4.1	Introduction	47
4.2	Optimum Bitumen Content	47
4.3	Moisture Induced Damage	51
4.4	Repeated Load Indirect Tensile	52
5	CONCLUSIONS AND RECOMMENDATIONS	54
5.1	Conclusions	54
5.2	Recommendations	56
	REFERENCES	58
	APPENDICES	60

LIST OF TABLES

TABLE.NO	TOPIC	PAGE
2.1	Causes and effects of low pavement stability (Asphalt Institute Manual Series 22)	7
2.2	Causes and effects of lack of durability (Asphalt Institute Manual Series 22)	7
2.3	Causes and effects of permeability (Asphalt Institute Manual Series 22)	7
2.4	Causes and effects of workability problems (Asphalt Institute Manual Series 22)	8
2.5	Causes and effects of poor fatigue resistance (Asphalt Institute Manual Series 22)	8
2.6	Causes and effects of poor skid resistance (Asphalt Institute Manual Series 22)	8
2.7	Typical design for dense-graded mix es designed by the Marshall Method for 75 blows compactive effort	11
2.8	Typical design for dense-graded mix es designed by the Marshall Method for 50 blows compactive effort	11
2.9	The comparison of air voids between 4 inch and 6 inch cores	18
2.10	The Lottman Test results	21
2.11	Recommendation of air voids according to the traffic conditions.	22
2.12	Compacted HMA Properties after Short and Long Term Aging	23
3.1	Gradation Limit for Asphaltic Concrete (ACW14)	27
3.2	Gradation Limit for Asphlatic Concrete (ACW20)	27

3.3	Design Bitumen Content	28
3.4	Test and Analysis Parameter for Asphaltic Concrete (JKR/SPJ/1988)	28
4.1	Analysis Parameter for ACW14 with 50 blows compaction at OBC 6 .1%	48
4.2	Analysis Parameter for ACW14 with 75 blows compaction at OBC 5.25%	49
4.3	Analysis Parameter for ACW20 with 50 blows compaction at OBC 4.6 %	49
4.4	Analysis Parameter for ACW20 with 75 blows compaction at OBC 4.6 5%	49
4.5	Tensile Strength for ACW20 with different number of blows	51
4.6	Resilient Modulus calculation results	53
4.7	Resilient Modulus parameter results	53

LIST OF FIGURES

FIGURE.NO	TOPIC	PAGE
1.1	Dry density and water content relationship	2
2.1	Design flow chart	10
2.2	Typical Marshall testing results	12
2.3	Compaction of Asphaltic Concrete by traffic	13
2.4	Hardening of bitumen by oxidation	14
2.5	Effects of compaction on permanent deformation for as compacted specimens, Oakland-Sutherlin project	15
2.6	Effects of compaction on permanent deformation for as compacted specimens, Castle Rock-Cedar Creek project	15
2.7	Effects of compaction on permanent deformation for as compacted specimens, Castle Rock-Cedar Creek project	16
2.8	Stiffness versus number of compaction blows	17
2.9	Illustration of Asphaltic Film Thickness	19
2.10	Illustration of VMA	20
2.11	Volume/mass relationships for a typical bituminous concrete	21
2.12	Asphalt Film Thickness vs. Resilient Modulus after Short Term Aging	24
2.13	Asphalt Film Thickness vs. Resilient Modulus after Long Term Aging	24
3.1	Laboratory Test Flow	29
3.2	Sieves from 75 μ m to 37.5mm	30
3.3	Procedure of Marshall Sample Preparation	35
3.4	Steps of Bulk Specific Gravity Test	38
3.5	Compression Testing Machine	38

3.6	Specimen in a vacuum container	42
3.7	Specimens placed in the freezer with temperature -18±3 ⁰ C	42
3.8	The specimens submerged in the water bath	43
3.9	The steps of Universal Testing Machine test	46

LIST OF APPENDICES

APPENDIX	TITLE	PAGE
A	Aggregates Gradation and Asphalt Content Percentage for Design.	6 0
B	Results of ACW 14 with 50 blows compactive effort	6 4
C	Results of ACW 14 with 75 blows compactive effort	6 9
D	Results of ACW 20 with 50 blows compactive effort	74
E	Results of ACW 20 with 75 blows compactive effort	79
F	Aggregates Gradation after OBC	84
G	Results and calculations for AASTHO T283	87
H	Results and calculations for ASTM D4123	92
I	Software results for ASTM D4123	95

CHAPTER 1

INTRODUCTION

Compaction is one of the most essential factors in designing and constructing the pavement. Besides, it is already known that the aim of compaction during the construction is to increase the pavement strength especially to the subgrade. This is because the whole strength of pavement is depending on the strength of the base soils. The importances of the compaction of soils are listed below.

1. To increase the shear strength and therefore bearing capacity,
2. To increase stiffness and therefore reduce the future settlement,
3. To decrease voids ratio and the permeability.

The Figure 1.1 below shows the effect of compaction to the soil density. If there is increasing number on compactive efforts, the optimum water content will decrease. The situation occurs because of the lowering air volume in the soils content.

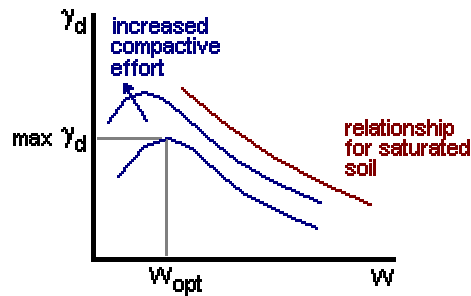


Figure 1.1 Dry density and water content relationship

The similar concept can be applied in the hot mix asphalt design. In the hot mix asphalt design the consideration is focusing on the optimum bitumen content in the laboratory compaction due to the optimum water content during construction work. The explanation on the concept is also similar in order to decrease the air void level to get the better result on pavement density.

The previous studies by Bell et al (1984) had shown that too high compaction could reduce the pavement durability and cause the fatigue condition. However, to get the actual causes of this condition, it is necessary to consider many factors and one of them is asphalt content. The amount of asphalt is dependent upon the amount of compactive effort. In this project, this situation was observed according to laboratory studies on hot mix asphalt (HMA) design. The effect of the compactive efforts on HMA performance was analyzed and recommendations were made.

1.1 Problem statement

In Malaysia, *Standard Specification for Road Works*, JKR/SPJ/1988, is used as a guideline to pavement construction according to Marshall laboratory design procedure. Besides, considering increasing the pavement thickness due to the traffic loads, the step made to extend the pavement life is by using high blows compactive effort in mix design.

Currently, 75 blows is used as the compactive effort in order to get the higher density of pavement. The density and asphalt pavement film thickness are both important. The concept of increasing the compaction is actually to reduce the air voids but the problem occurs when the asphalt thickness is also being reduce.

Prowell (2000) stated that Virginia Department of Transportation had modified their specifications on pavement design in 1990 to increase the compactive effort to 75 blows as response to rutting and flushing problem. Anyhow in year 2000, the Virginia's Asphalt Cooperative found that the 75 blows mix tures with lower asphalt content would not be durable.

The effect of the compactive effort was also stated by Pell (1987) as the maximum asphalt content increase the durability because the thick asphalt film do not age and harden as rapid as thin ones do.

The lack of asphalt thickness causing the cracking distress to the pavement. It is because the durability of the pavement is decreasing due to repetition loads and the fatigue condition start to occurs. Cracking could be more worse with the penetration of water during the rain and this will lead to pavemant failure.

The situation ia also indicated by Chadbourn et al (2000) that the thin asphalt film that coating is one of primary causes that leading the premature aging of asphalt binder. The lack of the film thickness is also allowing the air ox idizing the asphalt and the pavement will begin to brittle.

1.2 Objectives

The main objectives of this study are:

1. To evaluate the performance of asphaltic concrete mix es with 50 blows and 75 blows compactive effort.
2. To determine, the feasibility of using 50blows compactive effort in the heavy traffic loading pavement as compared to the current 75 blows compactive effort.

1.3 Scope of study

This study focused on asphalt concrete mix es that more on hot mix asphalt design by using Marshall Mix Design Method. The scope of study involved the laboratory tests according to specified guidelines. The effect of using 50 blows and 75 blows as compactive efforts in the mix designs were chosen to be the main criteria to analyze. Performance of two types of mix es, ACW14 and ACW20 was observed according to the serial tests. The test procedures were ex plained in Chapter 3.

1.4 Purpose of study

This study was used to evaluate the compactive efforts between 50 blows and 75 blows in the laboratory design as to give the ex planation according to the pavement densification that might occur because of over compaction. This study can be a reference to evaluate other studies according to the compactive effort performance in the pavement design.

1.5 Marshall Mix Design Method

The Marshall Method was developed by Bruce Marshall, bituminous engineer of Mississippi State Highway Department. U.S. Army Corps of Engineers had improved and used the method as common mix -design criteria after added some features to test procedure.

The main objective of the Marshall Method is to determine the optimum bitumen content and the properties of laboratory mix design to meet the construction requirement especially according to the optimum density and the air voids content.

The important features to study in the Marshall Method mix design are the density-voids analysis and the stability flow test of the compacted specimens. Chapter 2 discussed more about the previous study according to the mix designs.

REFERENCES

- American Association of State Highway and Transportation Officials (1990). *Standard Specifications for Transportation Materials and Method of Sampling and Testing*. 5th edition. Washington D.C: American Association of State Highway and Transportation Officials.
- American Society for Testing and Materials (1989). *Road and Paving Materials Traveled Surface Characteristics*. Volume 04.03. Philadelphia: American Society For Testing and Materials
- Asphalt Institute (1983). *Principles Of Construction Of Hot-Mix Asphalt Pavements*. USA: Lexington, Kentucky, MS-22.
- Bissada, A.F. (1984). Resistance to Compaction of Asphalt Mixtures and Its Relationship to Stiffness. In :Wagner F.T. ed., *Placement and Compaction of Asphalt Mixtures ASTM STP 829*. American Society for Testing and Materials. North California : Department of Transportation. 131-145
- Bell, C.A., Hicks, R.G. and Wilson, J.E. (1984). Effect of Percent Compaction on Asphalt Mixture Life In :Wagner F.T. ed., *Placement and Compaction of Asphalt Mixtures ASTM STP 829*. American Society for Testing and Materials. North California : Department of Transportation. 107-103
- Brown, E.R and Foo, K.Y (1989). *Evaluation of Variability in Resilient Modulus Test Results (ASTM D4123)*. N-CAT Report No 91-6 . Auburn University: National Centre of Asphalt Technology.
- Centerline (1999). *Mix Design and In-Place Air Voids*. Volume IV. Issues 2. West Virginia: Flexible Pavements Council of West Virginia.

- Chadbourn, B.A., Skok Jr., E.L., Chow, B.L., Spindler, S. and Newcomb, D.E. (2000). *The Effect of Voids in Mineral Aggregate (VMA) on Hot-Mix Asphalt Pavement*. Final Report. Minnesota Department of Transportation.
- Dickinson, E.J (1984). *Bituminous Road in Australia*. Australia Road Research Board.
- Huang, Y. H. (1993). *Pavement Analysis and Design*. New Jersey: Prentice-Hall.
- Hunter, E. R. and Ksaibati, K.(2002). *Evaluating Moisture Susceptibility of Asphalt Mixes*. Laramie : Department Civil and Architecture Engineering, University of Wyoming.
- Jabatan Kerja Raya (1988). *Standard Specification for Road Works*. Kuala Lumpur, (JKR/SPJ/1988). JKR 20401-0017-88.
- K.B de Vos and Feeley, A.J.(2001).*UTM-5P/14P Universal Testing Machine*. Hardware Reference. Ref:utm5-14p.doc.
- Khandal, P.S. and Chakraborty, S. (1996).*Evaluation of Voids in the Mineral Aggregate for HMA Paving Mixtures*. N-CAT Report No 91-6 . Auburn University: National Centre of Asphalt Technology.
- Khairul Nizam bin Mohd Yunus (2004). *Penggunaan Kaca Buangan Sebagai Agregat Halus Dalam Turapan Asfalt*. Universiti Teknologi Malaysia: Master Thesis.
- Mallick, R.B. (1997). *An Evaluation of Laboratory Compactors and Binder Aging Methods for Hot-Mix Asphalt (HMA)*. Auburn University: Ph.D Thesis.
- National Research Council (1991). *Asphalt Mixture: Design, Testing and Evaluation*. Transportation Research Record No 1317. Washington D.C: National Research Council.
- Pell, P.S. (1987). *Sixth International Conference of The Standard Design of Asphalt Pavement*. USA: University of Michigan.
- Prowell, B.D.(2000). *Design, Construction and Early Performance of Hot-Mix Asphalt Stabilizer and Modified Test Sections*. Virginia Transportation Research Council. VTRC 00-IR2.
- Roberts, F.L., Khandal, P.S., Brown, E. R., Lee, D.Y. and Kennedy, T.W.(1996). *Hot Mix Asphalt Materials, Mixture Design and Construction*. 2nd Edition. Lanham Maryland: NAPA Education Foundation.