UNIVERSITI PUTRA MALAYSIA

# EVALUATION OF A LABORATORY ASPHALT ROTARY COMPACTOR

HAMED HAGHIGHI

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**BY**

**HAMED HAGHIGHI**

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

**April 2009**

**DEDICATION**

This thesis is especially dedicated to:

*My lovely Wife:*

Masoomeh Tehranirokh

*My Praiseworthy Parents:*

Mohammad Ali Haghighi

&

Batool Ghofranpanah

*My Reverent In-laws:*

Hossein Tehranirokh

&

Fatemeh Ghasemi

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

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**Chairman:** **Associate Professor Ratnasamy Muniandy , PhD**

**Faculty:** **Engineering**

Several studies have shown that Marshall Compactor, California Kneading Compactor and Gyratory Compactor, the most conventional compactors, are not able to produce laboratory specimens that can truly represent the mixtures compacted in the field. However gyratory compactor fairly gives good simulation of the field roller compactor but no universally approved laboratory compactor has been developed to compact slabs for the wheel tracking and fatigue test. Compacting and preparing more than one sample at the same time is another matter of concern which these conventional compactors cannot achieve. Hence, a suitable laboratory compaction procedure is inevitable. Rotary compactor, a laboratory roller compactor was developed by researches from Universiti Putra Malaysia (UPM). This study was conducted to evaluate the performance of rotary compactor as a laboratory asphalt compactor and incorporated three objectives: to establish a laboratory protocol including procedures and standards for using the UPM rotary compactor, to evaluate the consistency of SMA slabs in terms of thickness and frictional resistance properties, and to validate the use of UPM rotary compactor in achieving the SMA

mixtures' requirements for bulk specific gravity, voids, Marshall stability and flow, resilient modulus and resistance to degradation. To compact a rotary slab to the desired thickness of 65 mm and 4% air voids, the applied pressure was recommended to start from 0 bar (as pre compaction) and stop at 1.5 bar with intervals of 0.25 bar. For each value of applied pressure, 6 number of passes (rotations) were needed (3 passes per each direction). The speed of rotation was recommended to be fixed on 10 Hz (3.29 RPM). Based on checking 315 points of three slabs to measure the thickness and the statistical analysis of these three slabs, the overall thickness of the slabs was almost uniform along the slabs. According to analyzing the performance of 132 core specimens it was concluded that rotary compactor was able to produce slabs with uniformly distributed properties such as volumetric properties, Marshall stability, flow and resilient modulus. Finally a degradation study was carried out to check and evaluate whether the aggregate structure was changed during the mixing and compacting. It was found that two aggregate fractions (12.7 mm and 9.5 mm) were affected and crushed during mixing and compacting procedures. To compensate the observed loss percentages a value called weight factor was introduced to provide the loss of materials.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia
Sebagai memenuhi keperluan untuk ljazah Master Sains

**PENILAIAN MESIN PENGGELEK PEMADATAN PEMADAT ASFALT DI MAKMAL**

Oleh

**HAMED HAGHIGHI**

**April 2009**

**Penyelia: Prof. Madya Ratnasamy Muniandy , PhD**

**Fakulti: Kejuruteraan**

Hasil beberapa kajian telah menunjukkan bahawa mesin pemadat Marshall, pemadat uli California dan pemadat berputar, adalah jenis mesin pemadat global yang paling konvensional, ia tidak mampu menghasilkan spesimen makmal yang yang benar-benar mewakili campuran yang telah dipadatkan seperti di tapak. Walaupun pemadat berputar dapat menghasilkan simulasi yang baik seperti mesin penggelek di tapak untuk tujuan pemadatan, tetapi ia tidak secara umumnya untuk diperkembangkan sebagai pemadat kepingan untuk wheel tracking dan ujian kelesuan. Pemadatan dan penyediaan lebih dari satu sampel pada satu masa yang sama adalah satu perkara yang perlu diberi perhatian yang mana ia tidak dapat diperolehi melalui pemadat konvensional. Oleh itu, satu prosedur pemadatan di makmal yang sesuai perlu diwujudkan. Mesin pemadat rotary, sejenis mesin penggelek telah dihasilkan dan diperkenalkan oleh penyelidik dari Universiti Putra Malaysia (UPM). Penyelidikan dan kajian ini dijalankan untuk menilai prestasi mesin penggelek ini sebagai pemadat asfalt dan telah menggabungkan tiga objektif utama; untuk menghasilkan protokol di makmal termasuk prosedur dan piawai dalam menggunakan alat ini, untuk menilai

konsistensi kepingan SMA dari segi ketebalan dan ciri- ciri rintangan geseran, dan untuk mengesahkan penggunaan mesin penggelek UPM dalam mencapai keperluan campuran SMA untuk spesifik graviti pukal, kandungan udara, kestabilan Marshall dan aliran, ketahanan modulus dan rintangan degradasi. Untuk memadatkan kepingan kepada ketebalan yang dikehendaki iaitu 65 mm dan 4% kandungan udara, tekanan yang disyorkan untuk dikenakan permulaannya dari 0 bar (sebagai pemadatan awal) dan berhenti pada 1.5 bar dengan selang rehat 0.25 bar. Untuk setiap nilai tekanan yang dikenakan enam nombor putaran diperlukan (3 untuk setiap arah putaran). Kelajuan putaran yang disyorkan adalah 10 Hz (3.29 RPM). Berdasarkan pemeriksaan ke atas 315 titik untuk tiga kepingan dalam mengukur ketebalan dan analisis statistik, kesemua tebal kepingan adalah hampir sama untuk setiap kepingan. Merujuk kepada analisis prestasi 132 spesimen, dapat disimpulkan yang mesin penggelek ini mampu menghasilkan kepingan yang hampir sama rata agihan sifatnya seperti kestabilan Marshall dan modulus ketahanannya. Akhir sekali, satu kajian penurunan (degradasi) dijalankan untuk mengkaji dan menilai sama ada struktur agregat telah berubah ketika proses campuran dan pemadatan. Telah dibuktikan yang dua pecahan agregat (12.7 mm dan 9.5 mm) telah dikesan dan telah pecah melalui proses campuran dan pemadatan. Untuk menggantikan peratus kekurangan yang telah dikesan, satu nilai yang dipanggil faktor berat telah diperkenalkan untuk memperlengkap kekurangan di dalam bahan yang digunakan.

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Last but not least, my very special thanks to all my friends who were directly and indirectly involved in this research and cooperated with this study.

I certify that a Thesis Examination Committee has met on 13 April 2009 to conduct the final examination of Hamed Haghighi on his thesis entitiled "Evaluation of a Laboratory Asphalt Rotary Compactor" in accordance with the Univesrities and University Colleges Act 1971 and the Constitution of the Universiti 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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Date: 9 July 2009

## DECLARATION

I hereby declare that the thesis is based on my original work as per program given to me, except for quotations and citations, which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at UPM or other institutions.

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**HAMED HAGHIGHI**

Date:

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| | |
|---|---|
| AAMAS | Asphalt Aggregate Mixture Analysis System |
| AASHTO | American Association of State Highway and Transportation Officials |
| AMIR | Asphalt Multi-Integrated Roller |
| ANOVA | Analysis of Variation |
| APA | Asphalt Pavement Analyzer |
| ASTM | American Society for Testing and Materials |
| AVC | Asphalt Vibratory Compactor |
| BS | British Standard |
| COV | Coefficient of Variation |
| EFB | Empty Fruit Bunch |
| ESAL | Equivalent Single Axle Load |
| FHWA | Federal Highway Administration |
| GTM | Gyratory Testing Machine |
| HMA | Hot Mix Asphalt |
| ITSM | Indirect Tensile Modulus Test |
| JIRCAS | Japan International Research Center for Agricultural Sciences |
| JKR | Jabatan Kerja Raya |
| LCPC | Laboratoire Central des Ponts et Chaussees |
| LVDT | Linear Variable Differential Transducer |
| LWT | Loaded Wheel Tracking |
| MATTA | Material Testing Apparatus |
| NAPA | National Asphalt Pavement Association |
| NCAT | National Center for Asphalt Technology |

| | |
|---|---|
| NCHRP | National Cooperative Highway Research Program |
| OGFC | Open Graded Friction Course |
| PLUS | Projek Lebuhraya Utara-Selatan |
| PTI | Pavement Technology Incorporation |
| RPM | Revolutions Per Minute |
| SGC | Superpave Gyratory Compactor |
| SHRP | Strategic Highway Research Program |
| SMA | Stone Matrix Asphalt |
| SSD | Saturated Surface Dry |
| Superpave | Superior Performing Asphalt Pavement |
| SWPE | Scott Wilson Pavement Engineering |
| TMD | Theoretical Maximum Density |
| UPM | Universiti Putra Malaysia |
| VCA | Voids in Coarse Aggregate |
| VFA | Voids filled with Asphalt |
| VMA | Voids in Mineral Aggregates |
| VTM | Voids in Total Mix |

# CHAPTER 1

# INTRODUCTION

## 1.1 General Background

The Malaysian road network has been expanding steadily, from 54,000 km in 1990 to about 80,000 km in 2007, including 78,300 km of State or Federal roads and 1,700 km of toll highways. The total number of registered vehicles has been exceeded 13 million and the average annual growth of vehicle ownership is over 7.0% per year whereas the increase in road length is less than 4.0% per annum as displayed in Figure 1.1 (Vellu, 2007).

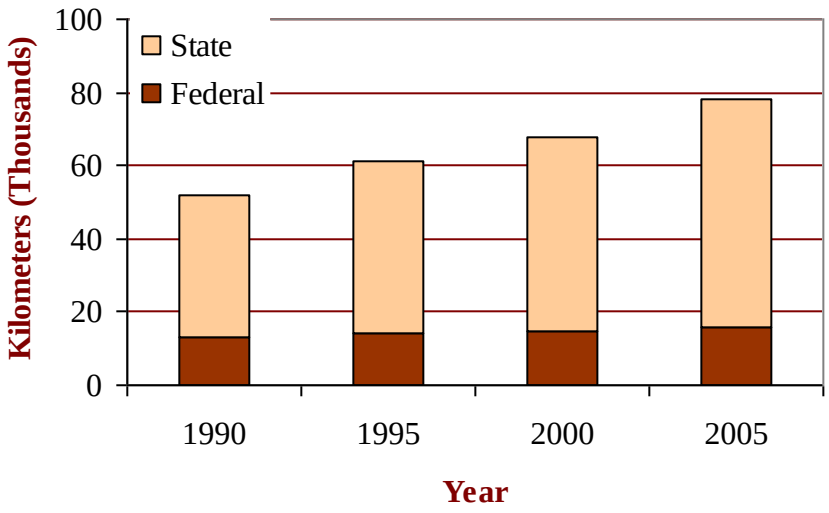


**Figure 1.1. Road Network Growth Trend**
**(Source: Vellu, 2007)**

Road transport continues to be the most popular way of transportation for both passenger and freight. Figure 1.2 shows 94.8% of passengers and 96.4% of freight movement are transported by road. This importance on road transport makes it difficult to the efficiency of the whole transport system. (Vellu, 2007)

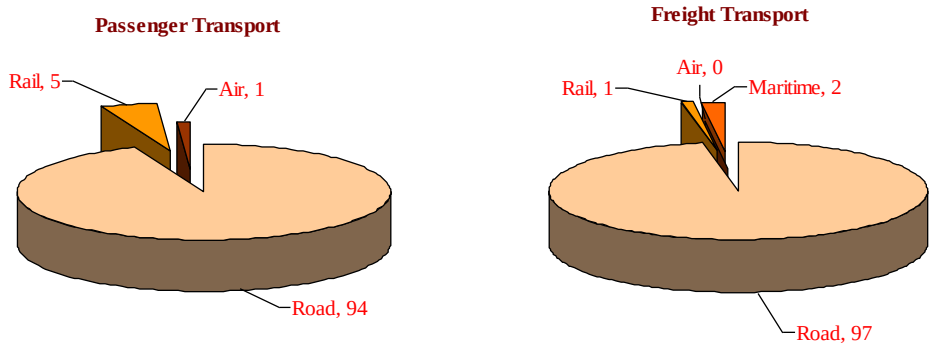


**Figure 1.2. Comparison of Road Use for Passenger and Freight Transport (Source: Vellu, 2007)**

Due to this high percentage of using the roads and the steady increase of vehicles there is a growing concern for comfort driving, safety, maintenance and environmental considerations, which has led to more durable, reliable, stronger and greener pavements, focusing particularly on asphalt mixtures.

Another considerable issue is the recent surge in global petroleum prices that has led to US$120 per each barrel of crude oil in June 2008 (Hendrickson, 2008). World consumption of crude oil has now reached 1000 barrels per second (Tertzakian, 2006). Thus most of the past practice and research in transportation engineering which had assumed reliance on petroleum for transportation fuel with fairly stable or declining petroleum prices cannot be no longer true.

Since the unit cost for constructing and maintaining roads has increased over the years, the road sector has to compete with other economic sectors for adequate funds. Efficient techniques in designing and constructing roads are therefore in demand and based on that, roads perform better and last longer. Stone Matrix Asphalt (SMA) is one type of asphalt mixtures which is a tough, stable and rut resistance mixture and relies on stone-to-stone contact to provide strength and a rich mortar binder to

provide durability. SMA generally contains about 70% of coarse aggregate and about 6-8% asphalt cement (Kast, 1985). For SMA Mix design several factors must be met. Among them are: to provide stone-on-stone contact through the selection of the proper gradation, to design an asphalt content at least 6 percent and air void content of 4 percent, to meet moisture susceptibility and draindown requirements and to design for voids in the mineral aggregate such that at least 17 percent is obtained (NAPA, 1999).

Development of SMA began in the 1960s in Germany and introduced in US in 1991. First full scaled field trial was carried out in Malaysia in 2005 (Shahid, 2008). Figure 1.3 shows the percentage of the SMA production from the total HMA production in some European countries in 2006 and also conveys the increase of SMA application. Based on the unique advantages of SMA and fast developing of it around the world, changing over to SMA seems inevitable.

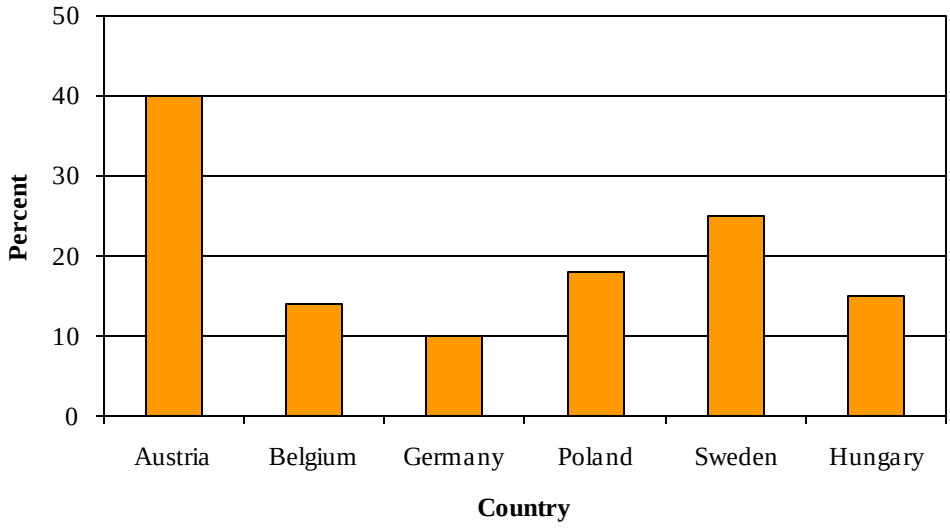


**Figure 1.3. Percent of Total Annual Hot Mix Asphalt Production in 2006 (Source: European Asphalt Pavement Association, 2006)**