UNIVERSITI TEKNOLOGI MARA

DEVELOPMENT OF MECHANISTIC FLEXIBLE PAVEMENT DESIGN METHOD FOR MALAYSIAN CONDITIONS

AHMAD KAMIL BIN ARSHAD

Thesis submitted in fulfillment of the requirements for the degree of Doctor of Philosophy

Faculty of Civil Engineering

March 2009
Candidate’s Declaration

I declare that the work in this thesis was carried out in accordance with the regulations of Universiti Teknologi MARA. It is original and is the result of my own work, unless otherwise indicated or acknowledged as referenced work. This topic has not been submitted to any other academic institution or non-academic institution for any other degree or qualification.

In the event that my thesis be found to violate the conditions mentioned above, I voluntarily waive the right of conferment of my degree and agree be subjected to the disciplinary rules and regulations of Universiti Teknologi MARA.

Name of Candidate: Ahmad Kamil Arshad
Candidate’s ID No.: 2004207237
Programme: Doctor of Philosophy in Civil Engineering (EC 990)
Faculty: Faculty of Civil Engineering
Thesis Title: Development of Mechanistic Flexible Pavement Design Method for Malaysian Conditions

Signature of Candidate: ____________________________
Date: 18/03/2009
ABSTRACT

Malaysia currently utilises an empirically-based pavement design procedure which is adopted from the AASHTO 1972 Design Guide. Elsewhere, pavement design approach is shifting towards mechanistic-based procedures that are based on the mechanics of materials. The purpose of this study is to develop a framework for mechanistic design of flexible pavement suitable for Malaysian conditions. In this study, resilient modulus characterisation of flexible pavement materials (asphaltic concrete wearing and binder course, base and subbase) used in Malaysia, according to the Public Works Department of Malaysia’s (PWD) Specification for Road Works (JKR/SPJ/1988), were carried out so that these can be used as inputs into a mechanistic-based procedure. Granite-type aggregates were used as it is produced by most quarries in Malaysia, and it is representative of the flexible pavement materials locally used. The repeated load indirect tensile test method (ASTM D4123-82) was used to investigate the effects of variations at different temperatures, gradation, bitumen content and penetration type and to determine the resilient modulus values of asphaltic concrete (ACW20 and ACB28). Regression models of ACW20 and ACB28 were developed and recommended for use as predictive models. Base (Type II) and subbase (Type E) were tested at different gradations and moisture contents using the repeated load triaxial test in accordance with AASHTO T307-99. From the test, the k-θ constitutive model was used to characterise the base and subbase materials. Field work data derived from the Falling Weight Deflectometer tests were compared to the values obtained from laboratory testing of asphaltic concrete, base and subbase materials and were found to be consistent for those sites where the thickness of the pavement materials were consistent and uniformly layered. The proposed mechanistic design procedure for Malaysian conditions consist of input (layer thickness, material properties and traffic loadings), pavement response model (to calculate stress, strain and deflection) and a distress model to relate the pavement responses to the number of traffic load repetitions to failure. For Malaysian conditions, it is imperative that environmental correction/modification factors (temperature and moisture) be incorporated into the regression models (for asphaltic concrete) and constitutive models (for base and subbase materials) to determine their resilient modulus values which will then used as inputs in the pavement analysis. The mechanistic analysis of pavement structures was carried out using a multi-layered elastic analysis software, KENLAYER. An example using the proposed method was then illustrated and a mechanistic-based pavement design table using the regression and constitutive models obtained in the laboratory tests was then deduced for a tyre pressure of 690 kPa (100 psi). It is recommended that for future research in this area, the proposed design process be verified by full-scale tests of actual pavement performance throughout their design life.
ACKNOWLEDGEMENTS

The author wishes to express his deepest gratitude and sincere appreciation to his thesis supervisor, Associate Professor Ir. Dr. Haji Mohd Yusof Abd Rahman and co-supervisor, Ir. Dr. Safri Haji Ahmad of JKR Malaysia, and Professor Mustaque Hossain of Kansas State University, United States for their invaluable assistance, encouragement and guidance during the research program.

Special acknowledgement is extended to the author’s parents, Arshad bin Ahmad and Fatimah bt. Abdullah for all their love, support and encouragement to the author from birth to the present time. The author would also like to thank all the teachers at Maktab Rendah Sains MARA, Kulim, Kedah and St. Xavier’s Branch School, Penang.

This research is also dedicated to all my relatives and friends in Kampung Pertama, Permatang Pauh, Seberang Perai and Kariah Masjid Kelawei, Pulau Tikus, Pulau Pinang.
# TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>TITLE PAGE</td>
<td>i</td>
</tr>
<tr>
<td>ABSTRACT</td>
<td>ii</td>
</tr>
<tr>
<td>ACKNOWLEDGEMENTS</td>
<td>iii</td>
</tr>
<tr>
<td>TABLE OF CONTENTS</td>
<td>iv</td>
</tr>
<tr>
<td>LIST OF TABLES</td>
<td>ix</td>
</tr>
<tr>
<td>LIST OF FIGURES</td>
<td>xii</td>
</tr>
<tr>
<td>LIST OF PLATES</td>
<td>xvi</td>
</tr>
</tbody>
</table>

## CHAPTER 1: INTRODUCTION

1.1 Background of Study                         | 1    |
1.2 Problem Statement                          | 2    |
1.3 Objective                                  | 4    |
1.4 Study Approach                             | 5    |
1.5 Scope and Limitations                      | 6    |
1.6 Significance of Study                      | 7    |
1.7 Summary                                    | 7    |

## CHAPTER 2: LITERATURE REVIEW

2.1 Introduction                               | 8    |
2.2 Empirical Methods                          | 9    |
2.3 Mechanistic Design Methods                 | 13   |
2.3.1 Input Parameters                         | 13   |
2.3.2 Structural Model                         | 14   |
2.3.3 Transfer Functions/Distress Models       | 19   |
2.3.4 Asphalt Institute Design Method          | 20   |
2.3.5 Shell Design Method                      | 22   |
2.4 Material Characterisation for Mechanistic Design Method | 24   |
2.4.1 Influence of Environmental Factors on Material Properties | 26   |