A Simplified Flexible Pavement Structure Design Method Based on Mathematical Model

A Thesis
Submitted to the Faculty of Engineering
Ain Shams University for the Fulfillment
of the Requirement of M. Sc. Degree in Civil Engineering
(Highway and Traffic Engineering)

Prepared by

AHMED ATEF MOHAMED

B.Sc. in Civil Engineering, June 2009
Faculty of Engineering, Ain Shams University

Supervisors

Prof. Eissa Abd Allah Sarhan,
Professor of Highway and Airport Engineering
Faculty of Engineering, Ain Shams University, Cairo, EGYPT

Prof. Khaled Anwar Kandil,
Professor of Highway and Airport Engineering
Faculty of Engineering, Ain Shams University, Cairo, EGYPT

Dr. Hamdy El-Sayed Mohamed
Lecturer Doctor of Highway and Airport Engineering
Faculty of Engineering, Ain Shams University, Cairo, EGYPT

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THESES APPROVAL

EXAMINERS COMMITTEE **SIGNATURE**

Prof. Layla Salah Eldein Radwan
Professor of Highway and Airport Engineering
Faculty of Engineering, Cairo University.

Prof. Eissa Abd Allah Sarhan
Professor of Highway and Airport Engineering
Faculty of Engineering, Ain Shams University.

Prof. Hassan Abd Elzaher Mahdy
Professor of Highway and Traffic Engineering
Faculty of Engineering, Ain Shams University.

Prof. Khaled Anwar Kandil
Professor of Highway and Airport Engineering
Faculty of Engineering, Ain Shams University.

Date: …. / …. / 2014

Statement

This dissertation is submitted to Ain Shams University, Faculty of Engineering for the degree of M. Sc. in Civil Engineering.

The work included in this thesis was carried out by the author in the department of Public Works, Faculty of Engineering, Ain Shams University, from 2010 to 2014.

No part of the thesis has been submitted for a degree or a qualification at any other University or Institution.

The candidate confirms that the work submitted is his own and that appropriate credit has been given where reference has been made to the work of others.

Date: …. / …. / 2014

Signature: …..…..……

Name: Ahmed Atef Mohamed

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ABSTRACT

The main objective of this research is to develop a simplified flexible pavement structure design method based on mathematical model depending on Egyptian available material and environmental conditions. There are several methods for pavement design used around the world. These methods could be classified into empirical methods or mechanistic-empirical methods. Empirical methods are not accurate and always depend on local conditions for material, traffic, and environment. Mechanistic methods are complicated to use.

In order to reach the main objective of this research, Egypt has been geographically divided into four zones based on temperature conditions during the year. First zone represents the northern of Egypt. Alexandria has been taken to represent this zone. Cairo has been taken to represent the second zone which is the middle of Egypt. The third zone is the southern Egypt and it is represented by Aswan. Finally, Sinai has been taken to represent the fourth zone which is the eastern of Egypt. Air temperature have been collected for the last five years for each city and converted to Asphalt temperature.

Layered elastic theory have been used to determine the maximum tensile strain at the bottom of asphalt layer and the maximum compressive strain at the top of subgrade layer for a group of pavement sections for each zone mentioned above. Sections were proposed based on Egyptian material characteristics and common used pavement sections. KENPAVE software has been used to determine tensile and compressive strains under a dual single axle load of 18klb weight at 36 points. These strains have been used to determine the allowable number of repetitions causing fatigue and rutting failure using Asphalt Institute models.

Mathematical models have been developed and ready to be used to determine the allowable number of repetitions. SGroup of tables have been also developed for flexible pavement design in Egypt. Balanced sections are determined from the output data. Balancing concept means that the pavement structure reaches both fatigue failure and rutting failure at the same time. Section is assumed to be balanced if the ratio between allowable number of repetitions causing fatigue and rutting is more than 90%. Balanced sections economically are recommended sections to be used in pavement design. So, similar tables for design have been developed based only on balanced sections.

Finally, a comparison between this method and the design method used in the Egyptian Code for Highway Design and Construction has been held. The used method in the Egyptian Code is the American Association of State Highway and Transportation Officials (AASHTO 1993). The AASHTO93 flexible pavement design method is a mechanistic-empirical method. The service road of the ring road in Cairo has been taken as a case study for this research. Flexible pavement section for this road has been designed based on AASHTO93 flexible pavement design method. The section has been evaluated using simplified flexible pavement design method.

KEY WORDS:
Flexible Pavement Design, KENPAVE, Layered Elastic Theory, Egyptian Catalogue for flexible pavement design.

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1. INTRODUCTION

1.1 Introduction

A highway pavement is a structure consisting of superimposed layers of processed materials above the natural soil subgrade. The main functions of pavement are to distribute the applied vehicle loads to the subgrade, to provide a good surface rideability and to provide an adequate skid resistance. The main two types that can meet the above mentioned functions are flexible pavements and rigid pavements.

Highway pavement is probably the most complex structure designed by engineers. This is because the structure layered form is unique as the layers are of different materials and none of the materials are linear elastic. In view of the aforementioned complexity, primitive pavement design methods are empirical, having evolved from the experience gained from constructing pavements, observing their performance and developing the design procedure based on this observed performance structural forms and materials which did not perform satisfactorily.

During World War II, aero planes rapidly became larger and heavier in order to be able to carry heavy bombs. Thus, it became necessary to build stronger pavements. Similar problems emerged on highway networks after the huge industrial evolution. Hence, there was a need to design pavements which will perform with increased efficiency for conditions beyond precious experience. The way to have a reliable flexible pavement design is to relate the pavement performance in the field with a theory of material that can predict the material behavior as a function of the material characteristics. This type of design is called mechanistic-empirical pavement design method.