The Development of Pavement Deterioration Models on the State Highway Network of New Zealand

Theunis F.P. Henning

Supervised by

Associate Professor Roger C.M. Dunn

and

Dr. Seósamh Costello

A thesis submitted in partial fulfilment of the requirements for the degree of Doctor of Philosophy in Engineering, The University of Auckland, 2008

Abstract

This thesis presents the results of developing road pavement deterioration models for the State Highway network in New Zealand pavement deterioration models are an integral part of pavement management systems, which are used to forecast long-term maintenance needs and funding requirements on a road network.

As part of this research, a Long-term Pavement Performance (LTPP) programme has been established on 63 sections of the State Highways. These sections are representative of typical road sections and climatic conditions on New Zealand roads. Data collection on these sections is undertaken on an annual basis and consists of high accuracy manual measurements. These measurements include road roughness, rutting, visual defect identification and strength testing with a Falling Weight Deflectometer.

Based on the LTPP data, new model formats for New Zealand conditions were developed including a crack initiation model and a three-stage rut progression model. The rut progression model consists of three stages, initial densification, stable rut growth and a probabilistic model to predict accelerated rut progression. The continuous probabilistic model developed predicts the initiation of pavement failure events such as crack initiation and accelerated rutting. It has been found that this model type has a strong agreement with actual pavement behaviour as it recognises a distribution of failure on roads rather than failure occurring at an particular point in time, namely, a year.

The modelling of rut progression in the three stages including, initial densification, stable rut progression and accelerated rutting has resulted in a significant increased understanding of this defect, especially for thin flexible chip seal pavements. It has been established that the in-service performance of these pavements is relatively predictable. However, incorporating both the in-service performance and the failure of pavements into one model was unrealistic. Therefore, by having the different stages of rutting, resulted into a more accurate forecasting of this defect.

Although this research has covered the two priority pavement models including cracking and rutting prediction, it has established the model framework for other pavement models to be developed. As more data become available, further work can be undertaken to

refine the models and to extend the research into the performance of alternative construction materials.

Dedication

For my wife:

"*Dankie Tania, sonder jou was dit nie moontlik nie*."

Proverbs 31:29

Acknowledgements

The following people and organisations are acknowledged for their contributions and input to the research:

PhD Supervisors

Associate Professor Roger C.M. Dunn

Dr. Seósamh Costello

Research Assistance

Derek Roux

Imedla Muljadi

Dr. Tim Watson

PhD Steering Committee

Prof. Bruce Melville

Dr. Christopher Bennett

Chris Parkman

Gordon Hart

Dr William Paterson

Dr. Gustav Rohde

Funding Organisations

New Zealand Transport Agency (formally Transit and Land Transport New Zealand)

Foundations for Research Science and Technology

MWH New Zealand Ltd.

Glossary of Terms

AADT	Annual average daily traffic
Distress modes	The method or process of failure of pavements, e.g. Cracking of the cemented base course normally occurs due to the tensile stresses at the bottom of the layer.
Calibration Coefficients	Constants applied to a numeric equation (model) to adjust the development of the model in order to make provision for external factors such as climatic or environmental conditions
ESA	Equivalent Standard Axles – the number of equivalent 80 kN axles
Falling Weight Deflectometer (FWD)	A stiffness test performed on pavement as an indicator of strength. A standard load is dropped from a standard height and resulting deflection is measured at given offsets.
Flexible Pavements	Pavements constructed with granular or asphalt materials.
HDM-III	World Bank Highway Design and Maintenance Standards Models
HDM-4	World Bank Development and Management Model
High-speed Data (HSD)	Various condition measurement instruments installed on a vehicle (e.g. roughness, rutting, texture and friction). The recorded measurements are automatically stored in electronic format based on a referencing system (e.g. linear or global positioning)
IRI	International Roughness Index (in mm/km)
Load associated cracking	Appears within the wheel tracks and is an indication of the induced traffic loading is starting to cause damage to the pavement
LTPP Sections	Long-Term Pavement Performance monitoring sections – designed to monitor pavement behaviour as a function of (amongst others) traffic, climate and maintenance.
Model	A numeric equation that quantifies the change of an outcome as a function of different input parameters
Pavement Deterioration	The decay of a pavement or surface as a result of traffic or environmental induced failure modes.
Pavement Management Systems (PMS)	A computer integrated system that incorporates network condition data with Long-Term maintenance planning processes. Most modern systems also include some form of pavement prediction capabilities
Repeatability	An indication of a measuring system being able to measure a consistent value when the measurements are repeated in the same location

Reproducibility	An indication that a measurement in one location would be statistically the same as a measurement undertaken in the same location after some time has past and the equipment had re-established in the same location
Sterilised Sites	A site that will received minimum maintenance only to ensure safety

Table of Contents

List of Figures

List of Tables