

1. INTRODUCTION

1.1 Introduction

Pavement structures consist of various natural and engineered materials that react to load input from vehicles in specific ways. As tyre loading is a time-dependent dynamic parameter, the response of the pavement system to the input is in reality time-dependent and transient.

Due to reasons such as lack of computational power, models and data, pavements have traditionally been analysed in a static mode, where it is assumed that the load input is a static time-independent parameter, and that the response of the pavement is also static and time-independent. Pavement engineers have long realised that this is not the ideal and actual situation, and various efforts into incorporating dynamic loading and transient pavement response were made.

Although different methods exist for incorporating moving dynamic tyre loads and transient pavement response into pavement design, these methods are not necessarily perfect and user-friendly. Limitations exist with regard to issues such as tyre load characterisation, material models, the ability (or lack of ability) to model non-symmetrical load conditions and the material properties to be used in the models. A need exists to provide a practical approach to transient pavement response analysis to real moving tyre loads.

1.2 Background

The purpose of pavement management is to ensure the lowest total cost of road transportation to society. Two sets of models are required to accomplish this. A set of models for determining the costs to society of different pavement conditions, for different traffic levels, traffic compositions and environments, and another set of models for predicting the future pavement condition as a function of traffic loading, climate, materials and maintenance are required. In addition a method for selecting the optimum combination of possible actions is required. A pavement's bearing capacity is not of immediate concern to a road user, but has an important influence on the rate at which the pavement deteriorates. If pavement engineering is to progress, theoretical models are certainly needed. However, the end goal of minimising the total cost to society (i.e. vehicle operating costs, user delay costs, accidents, noise, aesthetics etc) should not be forgotten. Although quantification of many of these costs is a political decision, the pavement engineer should develop the models to allow the politician to evaluate the consequences of his decisions (Ullidtz, 1997).

Most current pavement analysis, design and rehabilitation methods assume that the traffic using the pavement consists of vehicles running at static load levels, without allowance for variations in the load level along a specific road. Further, the interaction between tyre and pavement is not currently quantified. Therefore, the effect of dynamic loading (where a vehicle's load constantly

varies due to internal (vehicular) and external (road roughness) inputs) is not incorporated in the design philosophy or practice.

It has been shown internationally that vehicles do not exert a constant load on a pavement, but a dynamically varying load, with the magnitude depending on various input variables such as pavement profile, tyre and suspension characteristics, vehicle speeds, etc (Divine, 1997; Cebon, 1999). To enable optimal pavement design it is essential to determine the magnitude and characteristics of these effects, and whether or not it has any effect on the pavement performance and behaviour.

Conversely, knowledge of the effect of pavement surfaces on vehicles can also assist vehicle designers in optimising vehicle designs. It has been shown internationally that the dynamic loading effects of different vehicles differ, and knowledge of the effect of these vehicles on the pavement can further assist road agencies to plan and legislate against overloading (Divine, 1997). Locally it has been shown that the contact stresses developed between tyres and the road surface vary considerably among different types of tyres and operating conditions (De Beer et al, 1997).

1.3 Problem Statement

Current pavement design and analysis methods are based on simplifying assumptions regarding traffic loading (i.e. static constant loads) and material characteristics (i.e. linear elasticity). These assumptions cause implicit analysis errors that affect the reliability of the pavement analysis and subsequently affect the cost of a pavement, as these implicit errors must be accommodated in the final product.

1.4 Objectives of Study

The primary objectives of this study are twofold:

- a. To develop a practical systems framework to evaluate the various components in vehicle-pavement interaction, and
- b. To develop and verify a practical approach for the analysis of the transient response of pavement structures to dynamic input loads where appropriate.

This thesis focuses on providing a **practical** guideline for evaluating vehicle-pavement interaction from a pavement design viewpoint.

1.5 Scope

The overall scope of this thesis is the field of vehicle-pavement interaction, focussing on the dynamic load and transient response of the system. It falls within the scope and extent of this study to:

- a. Indicate the current understanding of vehicle-pavement interaction through a literature survey;
- b. Develop a holistic systems framework combining the various components of vehicle-pavement interaction;
- c. Populate the holistic framework with state-of-the-art available models, analysis techniques and data;
- d. Improve the models and analysis techniques where necessary to provide more realistic modelling capabilities and,
- e. Develop a practical approach for performing the transient pavement-structure analysis under appropriate conditions.

It falls outside the scope and extent of this study to:

- a. Investigate and develop new models and techniques for the vehicle part of the vehicle-pavement interaction system;
- b. Generate new data for evaluation with the model;
- c. Develop transfer functions for linking the stress and strain output from the model with expected pavement lives and economic issues, and
- d. Investigate the surfacing roughness-vehicle interaction.

1.6 Contribution to the State of Knowledge

Much work has already been done in the field of dynamic vehicle loading internationally. Major projects were launched by different organisations in which various aspects of dynamic loading and vehicle-pavement interaction have been measured and investigated, for example, Divine (1997).

Broadly the field of vehicle-pavement interaction needs research in various areas. These areas are both on the macro- (phenomenological) and micro-levels. On the micro-level the interaction between specific components needs investigation (i.e. tyre-pavement surfacing interaction). On the macro-level a phenomenological evaluation of the concept of vehicle-pavement interaction and the issues that need further detailed investigation are required.

It is the purpose of this study to contribute to the state of knowledge in terms of:

- a. Establishment of a holistic system approach to vehicle-pavement interaction in which the connections between the various components are defined;
- b. Provision of a simplified method for estimating the moving dynamic tyre load on a pavement, and
- c. Provision of a practical approach to transient pavement-structure response analyses for evaluating specifically South African pavement structures.

It is the longer-term view of the author that, subsequent to this study further work will be needed to investigate various detailed component level interactions that may be identified as in need of research through this study.

1.7 Layout of Thesis

This thesis consists of eight chapters. The relationships between the various chapters are shown schematically in Figure 1.1.

The thesis starts with a short introduction to the background and context of this study (*Chapter 1*). This is followed by a literature study on the current knowledge and practices with regard to the vehicle-pavement interaction phenomenon, the various vehicle and pavement components, and typical South African vehicles and pavements (*Chapter 2*). The aim of this chapter is to indicate the currently available approaches and techniques and the major limitations in these. It forms the basis for the further developments in the thesis. In *Chapter 3* the study approach developed for the research performed for the thesis is presented. Here the issues on which attention is focussed in the thesis are highlighted, and the approach to investigation of these issues discussed.

In *Chapter 4* a holistic vehicle-pavement interaction framework is developed. In this system the components identified as vital for dynamic vehicle-pavement interaction analyses are incorporated, and some issues related to the accurate analysis of the system discussed.

In *Chapter 5* the tyre loads generated using the various software packages are evaluated, and inferences regarding tyre loads are made. A simplified approach for determining moving dynamic tyre load populations is developed. Load populations for the pavement response evaluations in Chapter 6 are developed.

Chapter 6 is devoted to an investigation of the transient response of pavement structures to vehicle loading. It is the aim of this chapter to investigate the analysis of vehicle pavement interaction in terms of static and quasi-transient modes, and to determine the differences in analysis outcome due to different approaches. Typical current South African pavements are evaluated for different vehicle inputs, to determine the specific vehicle and pavement components of essence in transient analyses for South African conditions. Practical guidelines for vehicle-pavement interaction for pavement design of South African pavement structures are finally developed (*Chapter 7*). Some unresolved issues are also discussed in Chapter 7.

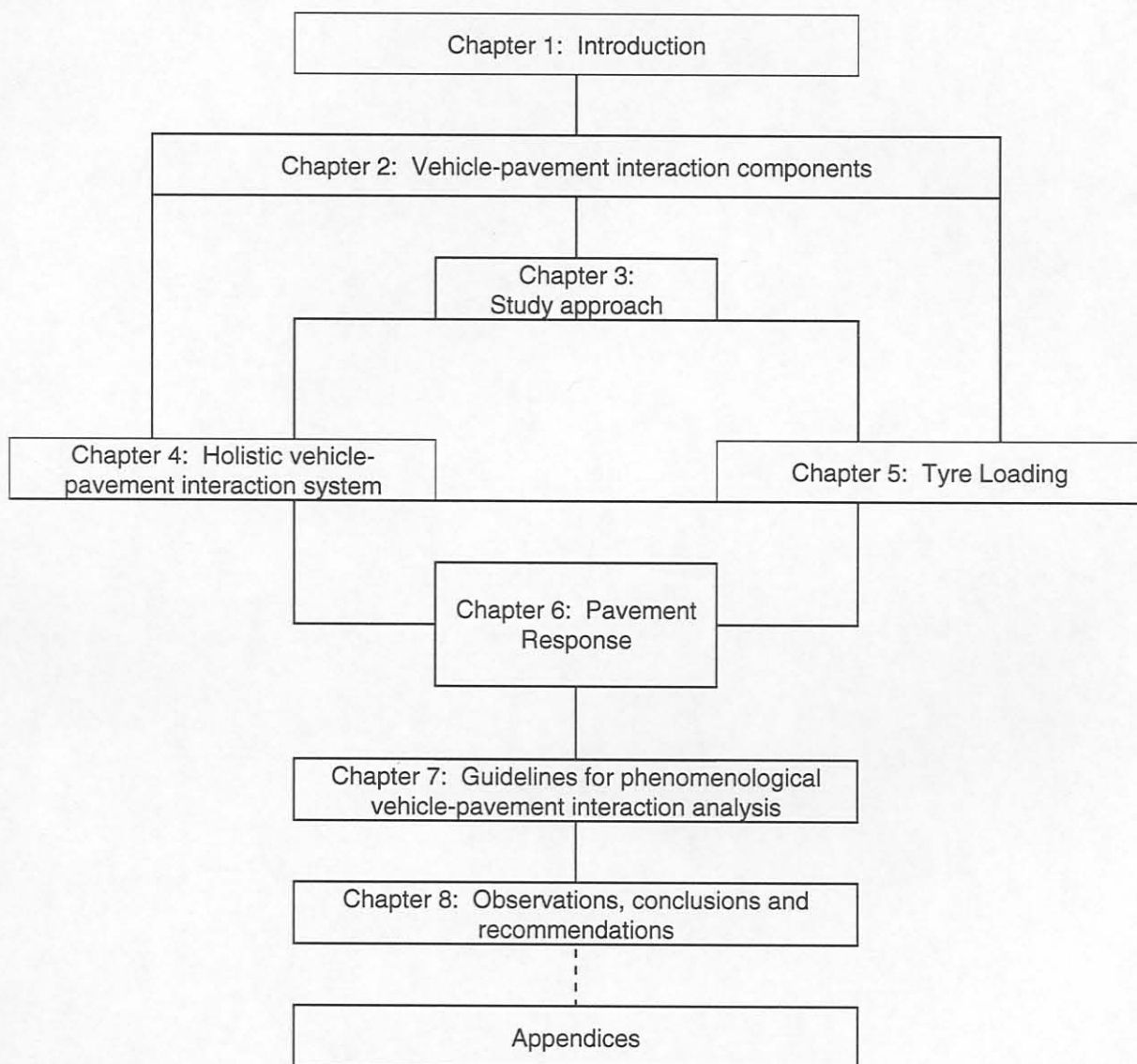


Figure 1.1: Schematic layout of thesis.

1.8 References

CEBON, D. 1999. **Handbook of Vehicle-Road Interaction**. Advances in Engineering 2, Lisse, The Netherlands: Swets & Zeitlinger.

DE BEER, M., FISHER, C. and JOOSTE, F.J. 1997. Determination of pneumatic tyre/pavement interface contact stresses under moving loads and some effects on pavements with thin asphalt surfacing layers. In: **8th International Conference on Asphalt Pavements**; (Proceedings of the 8th International Conference on Asphalt Pavements, held in Seattle, Washington, August 10-14 1997). Seattle, Washington.

DIVINE see **Dynamic Interaction of Vehicle & Infrastructure Experiment.**

Dynamic Interaction of Vehicle & Infrastructure Experiment: Asia-Pacific Concluding Conference. 1997. Melbourne, Australia: ARRB-TR.

ULLIDTZ, P. 1997. **Modelling flexible pavement response and performance.** Seattle, Washington: Instructor notes on nondestructive pavement analysis for the 8th International Conference on Asphalt Pavements Pre-Conference Technical Series.