# Considerations of Vehicle-Pavement Interaction for Pavement Design

by

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THESIS SUMMARY

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## SUMMARY

Pavement structures consist of combinations of materials that react to vehicle loading in specific ways. Vehicle loading and pavement response are time-dependent dynamic phenomena. Due to various reasons pavements have traditionally been analysed assuming that the load input and pavement response are static time-independent parameters. Pavement engineers have long realised that this is not the actual situation, and various efforts into incorporating dynamic loading and transient pavement response were made. It has been shown internationally that vehicles exert a dynamically varying load on the pavement, with the load magnitude depending on input variables such as pavement profile and vehicle component characteristics. It is essential to determine the magnitude and characteristics of these effects to enable optimal pavement design.

This thesis focuses on providing practical guidelines to characterising vehicle-pavement interaction from a pavement design viewpoint. The objectives focus on provision of a systems framework populated with models and data for the analysis of the transient response of pavement structures to dynamic tyre loads. It contributes to the state of knowledge mainly in development of a method for predicting moving dynamic tyre loads based on vehicle and pavement parameters, development of a method for estimating dynamic pavement response parameters based on static pavement response parameters, definitions for vehicle-pavement interaction studies, and an improved understanding of the issues relevant to vehicle-pavement interaction from a pavement design viewpoint in South Africa.

The method for predicting moving dynamic tyre loads is based on the knowledge that tyre load populations form a normal distribution, and that the parameters of this distribution can be predicted based on certain vehicle and pavement properties. The method can be used to develop moving dynamic tyre load populations for existing pavements to aid in providing optimum managerial decisions on maintenance and rehabilitation options and strategies.

The method for estimating the dynamic pavement response parameters based on static pavement response parameters is based on empirical relationships between static and dynamic pavement response parameters. It provides a tool to evaluate the possible effects of load speed on the population of expected pavement bearing capacities for a pavement structure.

The analyses and discussions contained in this thesis add to the current knowledge of vehicle-pavement interaction from a pavement design viewpoint, by highlighting dominant issues in such analyses. The effect of inadequate pavement maintenance and the resultant effect of inadequate pavement smoothness on moving dynamic tyre loads necessitate a new appreciation of issues such as quality control and pavement management, to ensure prime pavement quality for the entire pavement life.

Although this thesis provides an improved understanding of vehicle-pavement interaction for pavement design, much still needs to be done to improve this understanding. The recommendations in this thesis should be taken further to ultimately aid in the economic development of South Africa by ensuring a high-quality pavement network.

## KEYWORDS

vehicle-pavement interaction, pavement design, dynamic tyre load, transient pavement response, pavement roughness, component fingerprinting, terminology, guidelines, frequency analysis, vehicle-pavement interaction framework

## SAMEVATTING VAN PROEFSKRIF

# Beskouings oor Voertuig-Plaveisel Interaksie vir Plaveisel Ontwerp

deur

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## SAMEVATTING

Plaveisel strukture bestaan uit kombinasies van materiale wat op 'n spesifieke wyse reageer op voertuig belasting. Voertuig belasting en plaveisel respons is tyd-afhanklike dinamiese verskynsels. As gevolg van verskeie redes is plaveisels tradisioneel geanaliseer met die aaname dat die las inset en plaveisel respons statiese tyd-onafhanklike veranderlikes is. Plaveisel ingenieurs het lank reeds besef dat dit nie werklik die geval is nie, en verskeie pogings is aangewend om dinamiese belastings en plaveisel respons in te skakel by plaveisel ontwerp. Dit is internasionaal aangedui dat voertuie 'n dinamies veranderende belasting op plaveisels toepas, met die las grootte wat van inset veranderlikes soos die plaveisel profiel en voertuig komponent eienskappe afhang. Dit is belangrik om die grootte en eienskappe van hierdie tendense te bepaal, om optimale plaveisel ontwerp te verseker.

Hierdie proefskrif fokus op die voorsiening van praktiese riglyne vir die karakterisering van voertuig-plaveisel interaksie vanaf 'n plaveisel ontwerp oogpunt. Die doelwitte fokus op die daarstelling van 'n stelsel raamwerk waarin modelle en data gevoeg is vir analise van die bewegende respons van plaveisel strukture as gevolg van dinamiese bandlaste. Dit dra hoofsaaklik by tot die huidige kennis deur die ontwikkeling van 'n metode vir die voorspelling van bewegende dinamiese bandlaste gebaseer op voertuig en plaveisel veranderlikes, die ontwikkeling van 'n metode vir die berekening van dinamiese plaveisel reaksie veranderlikes gebaseer op statiese plaveisel reaksie veranderlikes, definisies vir voertuig-plaveisel interaksie studies en 'n verbeterde insig oor vraagstukke wat betrekking het op voertuig-plaveisel interaksie vanaf 'n plaveisel ontwerp oogpunt in Suid Afrika.

Die metode vir voorspelling van bewegende dinamiese bandlaste is gebaseer op die kennis dat bandlas populasies 'n normaal verdeling volg, en dat die veranderlikes van sodanige verdeling voorspel kan word met behulp van sekere voertuig en plaveisel eienskappe. Die metode kan gebruik word om bewegende dinamiese bandlas populasies vir bestaande plaveisels te ontwikkel, sodat optimale bestuursbesluite oor onderhoud en rehabilitasie opsies en strategië geneem kan word.

Die metode vir beraming van dinamiese plaveisel reaksie veranderlikes vanaf statiese plaveisel reaksie veranderlikes is gebaseer op empiriese verwantskappe tussen statiese en dinamiese plaveisel respons veranderlikes. Dit verskaf 'n metode om die moontlike effekte van las spoed op die populasie van verwagte plaveisel kapasiteit vir 'n plaveisel struktuur te bepaal.

Die analises en besprekings in hierdie proefskrif dra by tot die huidige kennis oor voertuig-plaveisel interaksie vanaf 'n plaveisel ontwerps oogpunt, deur die klem op belangrike vraagstukke in sodanige analises. Die effek van onvoldoende plaveisel onderhoud en die gevolglike effek van onvoldoende plaveisel gelykheid op bewegende dinamiese bandlaste, noodsaak 'n nuwe waardering van sake soos kwaliteits kontrole en plaveisel bestuur, om sodoende uitstekende plaveisel kwaliteit vir die volle plaveisel leeftyd te verseker.

Alhoewel hierdie proefskrif 'n verbeterde insig oor voertuig-plaveisel interaksie vanaf 'n plaveisel ontwerp oogpunt verskaf, is baie werk nog nodig om hierdie insig verder te verbeter. Die aanbevelings in hierdie proefskrif behoort verder geneem te word om uiteindelik tot die ekonomiese ontwikkeling van Suid Afrika by te dra deur die versekering van 'n hoë kwaliteit plaveisel netwerk.

## SLEUTELWOORDE

voertuig-plaveisel interaksie, plaveisel ontwerp, bewegende band laste, dinamiese plaveisel reaksie, plaveisel ongelykheid, komponent identifisering, terminologie, riglyne, frekwensie analise, voertuig-plaveisel interaksie raamwerk

## Opgedra aan Anita en my ouers

Gee aandag, luister na wat ek sê, let op, luister na my woorde:
Hou 'n boer aan met ploeg as hy wil saai? Hou hy aan grond breek en vore trek?
As hy die grond gelyk gemaak het, saai hy mos swartkomyn en komyn, sit hy koring en gars in waar dit moet kom en spelt aan die kante.
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Graan word gemaal vir brood, maar 'n mens hou nie eindeloos aan om dit te laat trap deur wawiele en deur trekdiere tot dit fyn is nie.
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# CONSIDERATIONS OF VEHICLE-PAVEMENT INTERACTION FOR PAVEMENT DESIGN

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# LIST OF ABBREVIATIONS

| | | |
|---|---|---|
| AC | - | Continuously graded Asphalt layer (used to designate thin asphalt layer in this dissertation) |
| AASHTO | - | American Association of State Highway and Transportation Officials |
| c | - | cohesion |
| CBR | - | California Bearing Ratio |
| CSIR | - | Council for Scientific and Industrial Research |
| CSRA | - | Committee for State Roads Authorities |
| DADS | - | Dynamic Analysis and Design System |
| DL | - | Dynamic Load |
| DLC | - | Dynamic Load Coefficient |
| DPSD | - | Displacement Power Spectral Density |
| DRTT | - | Division for Roads and Transport Technology |
| E80 | - | Equivalent 80 kN axle load (dual wheels) |
| $E_{eff}$ | - | Effective elastic modulus |
| $E_h$ | - | Horizontal effective elastic modulus |
| $E_v$ | - | Vertical effective elastic modulus |
| ELT | - | Effective Layer Thickness |
| MCL | - | Moving Constant Load |
| MDL | - | Moving Dynamic Load |
| HVS | - | Heavy Vehicle Simulator |
| OMC | - | Optimum Moisture Content |
| PADS | - | Pavement Analysis and Design Software |
| PSD | - | Power Spectral Density |
| SAMDM | - | South African Mechanistic Design Method |
| SL | - | Static Load |
| TFP | - | Tire Force Prediction programme |
| VRSPTA | - | Vehicle Road Surface Pressure Transducer Array |
| $\theta$ | - | Sum of the three principle stresses |
| $\varphi$ | - | Angle of internal friction of pavement material |
| $\mu\varepsilon$ | - | micro strain |
| $\sigma_{1,2,3}$ | - | Principle stresses |
| $\sigma_t$ | - | Tyre/pavement contact stress |