ASPECTS OF THE DESIGN AND BEHAVIOUR OF ROAD STRUCTURES INCORPORATING LIGHTLY CEMENTITIOUS LAYERS

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A DISSERTATION SUBMITTED AS PART FULFILMENT
for the DEGREE
DOCTOR OF PHILOSOPHY
in the
DEPARTMENT of CIVIL ENGINEERING
FACULTY OF ENGINEERING
UNIVERSITY OF PRETORIA

PRETORIA

FEBRUARY 1990

STATEMENT OF THE AUTHOR

The author hereby states that all the research work reported in this dissertation was initiated by him, and that he was solely responsible for the experimental planning and control of the various tests discussed, as well as the interpretation and reporting of all the results.

The execution of the tests (both laboratory and Heavy Vehicle Simulator (HVS)) was delegated by the author to the available technical assistants, under his direct supervision. The final copy-ready graphical illustrations were done by the drawing office.

.... *February 1990*

Morris De Beer

SUMMARY

Currently very sophisticated pavement design and evaluation methods exist. These methods include for example advanced computer programs and full scale pavement test facilities. However, there appears to be a lack in knowledge regarding actual structural behaviour of a wide variety of pavements and that the gap between theory and practice is not fully bridged yet.

Virtually no information on the behaviour of pavements with relatively lightly cementitious layers was available before this study. This study discusses various structural behavioural characteristics of these pavements, including objective classification based on the strength - balance of these pavements. Design and evaluation guidelines followed from this study are also given as an aid, and also to improve the understanding of basic pavement behaviour.

Chapter 1 discusses the introduction and background to this study, while Chapter 2 the scope and objectives are summarised.

In Chapter 3 the development of an objective in situ pavement classification system based on the results of the Dynamic Cone Penetrometer (DCP) is discussed. This classification is based on two unique parameters calculated from the DCP data, and these parameters describes the in situ strength - balance of the pavement. Deviations in the strength - balance is normally indicative of regions (layers) of relatively higher shear strength overlaying that of relatively lower strengths, or vice versa. This system has the potential to be applied to other flexible pavement types as well as sub - structures for rigid pavements.

In Chapter 4 the permanent deformation behaviour of pavements with cementitious layers is discussed. Most of this behaviour resulted from extensive studies conducted with the Heavy Vehicle Simulator (HVS) by the author. Specific attention is given to two basic types of pave—ments, viz a relatively deep and a relatively shallow pavement struc—ture. Two basic types of failure mechanisms associated with these pavements were identified and are discussed in detail. Investigation

into the rate of deformation indicated that this rate is linear and may assist largely in describing the structural capacities of these pavements. Relative damage was also investigated and is amongst others, strongly dependent on the basic pavement composition, loading, materials and environmental conditions.

Compression (crushing) failure of lightly cementitious layers was relatively unknown until this study, and Chapter 5 discusses in a somewhat original approach this behaviour. It is pointed out that compression failure of this materials occurs at very low levels of vertical compressive strains in these layers, and is strongly influenced by the in situ material strength and repetitive contact stress applications. The concept of **life to initiate compression failure** in these layers is introduced and may assist in more effective design and maintenance planning of these pavements.

In Chapter 6 the behaviour of the two types of pavement is described with the aid of the DCP, and indicates that this instrument aids largely in the correct identification of the actual failure mechanisms associated with these pavements. The concept of **pavement strength - balance paths** is introduced and provides a simple methodology to illustrate the structural changes in the pavement as a result of traffic loading, based on the classification system outlined in Chapter 1.

Resilient behaviour of pavements is always considered to be very important, especially when the pavement system and behaviour are described mechanistically with the aid of linear elastic theories or those which includes stress dependent parameters. Chapter 7 discusses the resilient responses of the two pavements investigated, and indicates the importance of factors such as surface and depth deflections, effective elastic moduli, induced stresses and strains. The concept of **effective fatigue life** for cementitious base layers is introduced and appears to describe the fatigue behaviour of these layers better than methods currently used in South Africa. Limiting vertical subgrade strain criteria were also verified for the pavements investigated here.

This dissertation also contains six appendices (Appendix A to F). In Appendices A, B and F supplementary results in the form of tables, figures and text are given to assist discussions in Chapters 4, 5, and 7. Appendix C outlines aspects of the various DCP computer programs which was developed during this study to assist in the formal preparation, evaluation and classification of the DCP data and graphical outputs, as discussed in Chapter 3. A photographic record of most of the HVS tests conducted during this study is given in Appendix D. Appendix E summarises the graphical computer output generated by the mentioned computer programs, for most of the HVS tests conducted in this study, and are self explanatory. The DCP data in this appendix is used in Chapter 6.

SAMEVATTING

Huidiglik bestaan daar heelwat gesofistikeerde plaveiselontwerp- en evaluerings metodes. Hoogsgevorderde rekenaarprogrammatuur asook onder andere volskaalse-toetsfasiliteite vir plaveisels is ń geruime tyd al beskikbaar. Daar is egter nog ń tekort aan inligting en kennis rakende die werklike strukturelegedrag van ń verskeidenheid van plaveisels en die gaping tussen die teorie en praktyk is nog nie heeltemaal oorbrug nie. Feitelik geen inligting van die gedrag van plaveisels met relatiewe lig gesementeerdelae was bekend voor hierdie studie nie. In hierdie studie word ń verskeidenheid van gedragskarakteristieke van hierdie plaveisels bespreek, en sluit onder andere ń objektiewe plaveisel-klassifikasiesisteem in, gebaseer op die sterktebalans van plaveisels. Riglyne ten opsigte van die ontwerp en evaluering vloei uit die studie voort en word as ń hulpmiddel gegee om basiese plaveiselgedrag beter te verstaan.

Hoofstuk 1 bespreek die inleiding asook die breë agtergrond tot hierdie studie, terwyl in Hoofstuk 2 die omvang en doelwitte saamgevat word.

In Hoofstuk 3 word die ontwikkeling van ń objektiewe in situ plaveisel-klassifikasiesisteem, gebaseer op die resultate van die Dinamiese Keëlpenetrometer (DKP) bespreek. Hierdie klassifikasie is gebaseer op twee unieke parameters wat vanuit die DKP-data bereken word. Hierdie parameters beskryf die in situ sterktebalans van die plaveisel. Afwykings in die sterktebalans is normaalweg ń aanduiding van gebiede of gelaagheid van relatiewe hoë skuifsterkte bo-op gebiede met relatiewe lae skuifsterkte, of omgekeerd. Hierdie sisteem het die potentiaal om ook gebruik te kan word op ander buigbareplaveisels tipes, asook die onderlaagstrukture van starplaveisels.

In Hoofstuk 4 word die permanentedeformasiegedrag van plaveisels met gesementeerdelae bespreek. Die meerderheid van hierdie gedrag is bestudeer tydens uitgebreide studies met die Swaar Voertuignabootser (SVN), deur die skrywer. Spesiale aandag is geskenk aan twee basiese tipes plaveisels, nl ń diep en ń vlak plaveiselstruktuur. Twee basiese tipes swigmeganismes eie aan hierdie plaveisels is geïdentifiseer, en

word in detail bespreek. Ondersoek na die tempo van deformasie het aangedui dat hierdie tempo lineêr is en grootliks gebruik kan word om die strukturele kapasiteit van die plaveisels te beskryf. Die relatiewe skade asgevolg van verskillende wielbelastings is ook ondersoek en hang sterk van heelwat faktore af, soos byvoorbeeld basiese plaveiselsamestelling, belasting, materiale en omgewings toestande.

Drukswigting (vergruising) van lig gesementeerde plaveisellae was redelik onbekend tot en met hierdie studie, en word in Hoofstuk 5 word op ń ietwat oorspronklike wyse benader. Dit word uitgewys dat drukswigting van hierdie materiale by baie lae vlakke van vertikale-drukvervorming voorkom, en word beheer deur die in situ materiaalsterkte en herhalende bandkontakspanning. Die konsep van **lewe tot die inisiering van drukswigting** in hierdie lae word voorgestel en mag meer effektiewe ontwerp - en onderhoudsbeplanning tot gevolg hê.

In Hoofstuk 6 word dir gedrag van hierdie twee tipes plaveisels na aanleiding van die DKP-resultate bespreek en dit word aangedui dat hierdie instrument baie handig is in die identifisering van die korrekte swigmeganisme wat met hierdie plaveisels geassosieer is. Die konsep van **plaveiselsterktebalansroetes** word voorgestel en voorsien ń eenvoudige metode om die strukturele veranderings as gevolg van verkeersbelasting van die plaveisel te illustreer. Hierdie konsep is gebaseer op die klassifikasiesisteem, soos beskryf in Hoofstuk 1.

Die veerkragtigheidsgedrag van plaveisels word nog altyd as baie belangrik beskou, veral met die beskrywing van die meganistiesegedrag van die plaveiselsisteem met behulp van die lineêr elastiese teorie asook teorië wat spanningsafhanklike parameters gebruik. Hoofstuk 7 bespreek die veerkragtigheids-responsie van die twee plaveisels wat ondersoek is, en toon die belangrikheid aan van faktore soos die oppervlak- en dieptedefleksies, effektiewe-elastisitietsmoduli, gegenereerde spannings en vervormings. Die konsep van **effektiewe-vermoeïngslewe** vir gesementeerdekroonlae word voorgestel, en beskryf blykbaar die vermoeïngsgedrag van hierdie lae beter as huidige metodes in Suid Afrika. Vertikale-grondlaag-vervormingskriteria is ook ondersoek vir hierdie plaveisels, en word ook bespreek in hierdie hoofstuk.

Hierdie proefskrif bevat ook ses aanhangsels (Aanhangsel A tot F). In Aanhangsels A, B en F word verdere verklarende resultate vir Hoofstukke 4, 5, en 7 in die vorm van tabelle, figure en teks gegee. Aanhangsel C toon sekere aspekte van die rekenaarprogrammatuur aan, wat tydens hierdie studie ontwikkel is om die formele aanbieding, evaluasie en klassifisering van die DKP-data asook grafiese-uitdrukke moontlik te maak, soos beskryf in Hoofstuk 3. ǹ Fotografiese samevatting van die meeste van die SVN-toetse wat tydens hierdie studie gedoen is word in Aanhangsel D gegee. Aanhangsel E bevat in opsommende vorm, die grafiese-uitdrukke van die DKP-resultate van die meeste van die SVN-toetse. Hierdie uitdrukke bevat die basiese DKP-inligting wat in Hoofstuk 6 gebruik is.

AAN : MARION, MORRIS (jnr) en FREDERIK

ACKNOWLEDGEMENTS

I would like to express my honest and sincere thanks to the following persons and organisations:

Dr S H Kuhn, former Chief Director and Dr C R Freeme, Director of the Division for Transport and Road Research (DRTT) of the CSIR, for the opportunity to do this study and to complete a dissertation on this subject.

My former Group Head of the former Pavement Engineering Group at NITRR, Dr C R Freeme, for his interest, advice and many valuable discussions during the period of accelerated testing of the pavements studied.

My co - superviser Professor P F Savage, for his interest, advice and valuable discussions on the contents of this dissertation.

Mr L J Terblanche, Executive Director of the Roads Branch of the Transvaal Provincial Administration (TPA), for the opportunity to use their Heavy Vehicle Simulator (HVS) and results during this study.

Mr E G Kleyn, Chief Materials Engineer, Roads Branch of the TPA, for his keen interest, advice and many valuable and often exciting discussions during this period of study.

Dr E Horak, Programme Manager of the Pavement Engineering Technology Programme at DRTT, for his continuous support, interest and valuable discussions.

Messers N Kuhn, J M Collett, L Marks, N Ras, S Lacante and their technical teams for their assistance with the substantial amount of HVS data collection and reporting. Without their help it would have been impossible to complete this study.

Mrs Y E Diering and B E Saler of the Drawing office for their help in the preparation of all the drawings.

All my other colleagues in the Division for their help and support during this study.

Ook ŉ spesiale woord van dank aan my vrou - Marion, baie dankie vir die geduld, ondersteuning en liefde wat ek van jou gekry het tydens hierdie periode van intensiewe studie.

En dan my grootste dankbaarheid aan GOD wat my ook hierin gelei het.

SOLI DEO GLORIA !

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