

DISSERTATION SUMMARY

A STRUCTURAL DESIGN PROCEDURE FOR EMULSION TREATED PAVEMENT LAYERS

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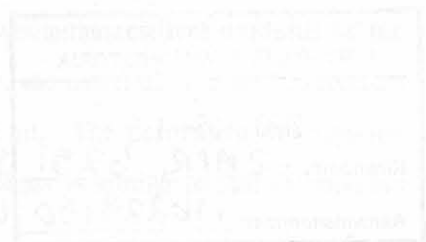
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- University:** University of Pretoria
- Degree:** Master of Engineering (Transportation Engineering)

The use of bitumen emulsion treated pavement layers is well established and is becoming more popular in road building. Current structural design procedures include mainly empirical methods or methods derived from laboratory studies. No design method based on results from accelerated pavement testing of full scale pavements currently exists and no provision for emulsion treated materials exists in the South African Mechanistic Pavement Design Method or the TRH4 structural design guideline document on flexible pavements.

The need therefore existed to provide some guidelines on the structural design of emulsion treated materials based on accelerated pavement testing on a full-scale pavement. The aim of this research was to provide interim guidelines for the structural design from accelerated pavement testing supported by relevant laboratory testing.

A test section, constructed with an emulsion treated ferricrete, was subjected to Heavy Vehicle Simulator testing. Samples from the test site were tested in the laboratory to investigate the engineering properties of the material under different bitumen and cement contents. The laboratory study was used to determine parameters, which are important to the structural design procedure. Results from the laboratory study indicated that the cement content contributes towards the strength of the material, while the bitumen content contributes towards the flexibility of the material.

Results with the Heavy Vehicle Simulator indicated that the test section had a good resistance to permanent deformation. It was determined that the behaviour of the material was two-phased, similar to that of lightly cemented materials. During the first phase, the material demonstrates fatigue properties. The end of the fatigue life phase was defined to be when the resilient modulus of the material reduced to a value of 500 MPa. During the second phase, the material is in an "equivalent granular" phase with a reduced resistance to permanent deformation. The permanent deformation resistance behaviour of an emulsion treated material in its second phase is similar to that of unbound

granular materials. The concept of the stress ratio was introduced to describe the permanent deformation behaviour.

Failure criteria for fatigue and permanent deformation were developed and presented as a transfer function that can be used in the South African Mechanistic Pavement Design Method. The transfer functions were developed for different road categories and a design procedure is proposed.

Finally, a design catalogue for emulsion treated base layers was developed from these transfer functions and is presented.

SAMEVATTING VAN VERHANDELING

STRUKTURELE ONTWERPMETODE VIR EMULSIE BEHANDELDE PLAVEISELLAE

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Die gebruik van bitumen emulsie behandelde plaveisellae is goed gevestig en word al hoe meer populêr in die bou van paaie. Huidige ontwerpprosedures bestaan meestal uit empiriese metodes, of metodes ontwikkel uit suiwer laboratoriumstudies. Geen ontwerpmetode wat gebaseer is op volskaalse plaveiseltoetse bestaan tans vir emulsie behandelde materiale nie. Daar word ook nie voorsiening gemaak in die Suid-Afrikaanse Meganitiese Plaveiselontwerpmetode, of die TRH4, vir die gebruik emulsie behandeling nie.

Daar bestaan dus 'n behoefte na riglyne vir die strukturele ontwerp van emulsie behandelde materiale wat gebaseer is op volskaalse plaveiseltoetse. Die doel van hierdie studie was om voorlopige riglyne daar te stel vir die strukturele ontwerp van hierdie materiale wat verkry is uit die volskaalse plaveiseltoetse en relevante laboratoriumtoetse.

'n Toetsseksie van emulsie behandelde ferrikreet is gebou en onderwerp aan toetse met die Swaarvoertuignabootser. Monsters van die toetsseksie is in die laboratorium getoets om the invloed van verskillende sement en bitumen inhoude op die ingenieurseienskappe van die materiaal te ondersoek. Parameters wat belangrik is vir die strukturele ontwerp van emulsie behandelde materiale is in dié laboratoriumstudie bepaal. Resultate van die laboratoriumstudie dui aan dat die sement hoofsaaklik verantwoordelik is vir die sterkte van die materiaal, terwyl die bitumen bydra tot the buigsaamheid.

Die toetse onder die Swaarvoertuignabootser het daarop gewys dat die materiaal redelike goeie weerstand teen permanente vervormings besit. Dit is verder ontdek dat emulsie behandelde materiale 'n twee fase gedrag het wat soortgelyk is aan die van liggeselementeerde materiale. Gedurende die eerste fase het die materiaal vermoeiingseienskappe getoon. Die einde van dié fase is gedefinieer wanneer die elastiese veerkragsmodulus 'n waarde van 500 MPa bereik. Die tweede fase is 'n "ekwiwalente granulêre fase" waar die materiaal 'n verminderde weerstand teen permanente

vervorming het. Die permanente vervormingsgedrag van die materiaal is dieselfde as die van granulêre materiale. Die konsep van Spanningsverhouding, om die permanente vervormingsgedrag van die materiaal te beskryf, is voorgestel.

'n Swigtingsstandaard vir die vermoeiingsleeftyd en permanente vervorming is ontwikkel in die vorm van oorgangsfunksies, wat in die Suid-Afrikaanse Meganitiese Plaveiselontwerpmetode gebruik kan word. Die oorgangsfunksies is ontwikkel vir die verskillende kategorieë paaie in Suid Afrika.

Laastens is 'n katalogus ontwikkel vanaf die oorgangsfunksies wat die ontwerp van emulsie behandelde materiale kan vergemaklik. Die katalogus is ingesluit.

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TABLE OF CONTENTS

CHAPTER 1 INTRODUCTION AND OBJECTIVES.....	1-1
1.1 Historical background.....	1-1
1.2 The use of bitumen emulsion in base layers.	1-2
1.3 The South African Mechanistic Pavement Design Procedure	1-3
1.4 The need for a formal design procedure for pavements with emulsion treated layers.	1-4
1.5 Objectives of the study	1-4
1.6 Scope and extent of the study	1-4
1.7 Structure of the dissertation.	1-5
1.8 References.....	1-5
 CHAPTER 2 MIX DESIGN AND ENGINEERING PROPERTIES OF EMULSION TREATED MATERIALS	 2-1
2.1 Introduction.....	2-1
2.2 History and background of emulsion treated material mix design	2-1
2.3 Emulsion treated material mix design in South Africa	2-2
2.4 The engineering properties of emulsion treated materials	2-5
2.5 Curing of emulsion treated layers.....	2-8
2.6 Conclusions.....	2-8
2.7 References.....	2-9
 CHAPTER 3 STATE OF THE ART ON THE STRUCTURAL BEHAVIOUR AND DESIGN OF EMULSION TREATED PAVEMENT LAYERS.....	 3-1
3.1 Introduction.....	3-1
3.2 The history and background to structural design of pavements containing emulsion treated materials.....	3-1
3.3 Failure mechanism of emulsion treated layers.....	3-2
3.4 The behaviour of emulsion treated pavement layers	3-3
3.5 Structural design of emulsion treated materials.....	3-7
3.6 References.....	3-21
 CHAPTER 4 MECHANISTIC-EMPIRICAL DESIGN MODELS IN PAVEMENT ENGINEERING.....	 4-1
4.1 Introduction to the Mechanistic – Empirical approach.....	4-1
4.2 Prerequisites for incorporating a new material into the mechanistic-empirical design process	4-1

4.3	Granular materials.....	4-2
4.4	Cemented layers.....	4-6
4.5	Asphalt materials	4-12
4.6	Subgrade materials.....	4-14
4.7	Mechanistic-empirical models applicable to emulsion treated materials.	4-16
4.8	Conclusions.....	4-17
4.9	References.....	4-18
CHAPTER 5 PERFORMANCE OF AN EMULSION TREATED GRAVEL UNDER LABORATORY AND HVS TESTING		5-1
5.1	Introduction.....	5-1
5.2	Experimental design	5-1
5.3	The influence of net bitumen and cement contents on the strength and flexibility of emulsion treated gravel materials	5-12
5.4	Static shear strength.....	5-20
5.5	Laboratory Elastic modulus (M_R)	5-22
5.6	Permanent deformation from dynamic triaxial testing	5-26
5.7	Heavy Vehicle Simulator (HVS)	5-28
5.8	Conclusions.....	5-39
5.9	Recommendations.....	5-41
5.10	References.....	5-42
CHAPTER 6 FATIGUE PROPERTIES OF EMULSION TREATED MATERIALS		6-1
6.1	Introduction.....	6-1
6.2	The end of the fatigue life.....	6-1
6.3	Tensile strain analysis.....	6-2
6.4	The Effective fatigue life of emulsion treated materials.....	6-5
6.5	Confidence limits.....	6-9
6.6	Fatigue life damage factor	6-11
6.7	Conclusions.....	6-12
6.8	References.....	6-12
CHAPTER 7 PERMANENT DEFORMATION PROPERTIES OF EMULSION TREATED MATERIALS		7-1
7.1	Introduction.....	7-1
7.2	Factors influencing the development of permanent deformation under repetitive loading	7-1
7.3	Permanent deformation model from Heavy Vehicle Simulator Data	7-1
7.4	Mechanistic analysis of Heavy Vehicle Simulator pavement for permanent deformation.....	7-2

7.5	Permanent deformation transfer function	7-7
7.6	Permanent deformation damage factor	7-12
7.7	Conclusions.....	7-13
7.8	References.....	7-13
CHAPTER 8 THE STRUCTURAL DESIGN OF EMULSION TREATED MATERIALS.....		8-1
8.1	Introduction.....	8-1
8.2	General pavement behaviour	8-3
8.3	Behaviour of emulsion treated materials	8-4
8.4	Material classification.....	8-5
8.5	Mechanistic analysis of emulsion treated pavement.....	8-9
8.6	Design catalogue.....	8-14
8.7	References.....	8-18
CHAPTER 9 CONCLUSIONS AND RECOMMENDATIONS.....		9-1
9.1	Conclusions.....	9-1
9.2	Recommendations.....	9-3
APPENDIX A.LABORATORY TEST RESULTS.....		A
APPENDIX B.OPTICAL MICROSCOPE PICTURES.....		B
APPENDIX C.SELECTED HEAVY VEHICLE SIMULATOR RESULTS.....		C
APPENDIX D.CONTOUR PLOTS OF STRESSES UNDER DUAL WHEEL LOAD.....		D
APPENDIX E.CALCULATION SHEETS FOR PAVEMENT STRUCTURES IN		
DESIGN CATALOGUE.....		E

LIST OF TABLES

Table 2.1	Mix design criteria for ETB's in terms of CBR and UCS.....	2-5
Table 3.1	LTPP sections for pavements with emulsion treated layers.....	3-3
Table 3.2	Early cure reduction factors for strength development of emulsion treated layers.....	3-10
Table 3.3	Suggested structural coefficients for recycled layers.....	3-12
Table 3.4	Resilient modulus values of emulsion treated base layers for each quarter for different full cure periods.....	3-13
Table 3.5	Average base temperatures in southern Africa.....	3-13
Table 3.6	Material properties for emulsion treated materials using the modification approach.....	3-15
Table 3.7	Allowable minimum safety factors at various traffic levels.....	3-16
Table 4.1	Allowable safety factors for granular materials at various traffic levels.....	4-3
Table 4.2	Typical effective range of elastic moduli for cement treated materials in various stages of behaviour.....	4-9
Table 4.3	Maximum allowable tensile strain in the bituminous layer according to Dormon and Metcalf (1964).....	4-13
Table 5.1	Tests on different combinations of cement and net bitumen contents.....	5-2
Table 5.2	Summary of HVS testing on sections 410A4, 410B4 and 412A4.....	5-11
Table 5.3	Summary of California Bearing Ratio (CBR) test results (0% cement).....	5-12
Table 5.4	Summary of Unconfined Compressive Strength (UCS) test results.....	5-13
Table 5.5	Summary of Indirect Tensile Strength (ITS) test results.....	5-14
Table 5.6	Summary of flexural beam fatigue test results.....	5-16
Table 5.7	Static triaxial test results calculated directly from M6hr circles.....	5-21
Table 5.8	Elastic modulus test results from the dynamic triaxial tests.....	5-24
Table 5.9	Summary of permanent deformation results from HVS tests.....	5-30
Table 5.10	Maximum deflection at end of test.....	5-31
Table 5.11	Crack development on HVS test sections.....	5-34
Table 5.12	Summary of backcalculated E moduli for HVS test sections.....	5-37
Table 5.13	Proposed values for strain at break for emulsion treated materials.....	5-41
Table 6.1	Life to crack initiation.....	6-4
Table 6.2	Effective fatigue life.....	6-6
Table 6.3	Confidence limits for different road categories.....	6-9
Table 6.4	Fatigue life damage factors for emulsion-treated gravel.....	6-12
Table 7.1	Permanent deformation life damage factors for emulsion-treated gravel.....	7-12
Table 8.1	Definition of main road categories used in pavement design.....	8-2
Table 8.2	Traffic classes according to TRH4:1996.....	8-3
Table 8.3	Proposed Classification of Emulsion treated materials.....	8-6

Table 8.4 Typical composition of emulsion treated material per class8-7

Table 8.5 Proposed emulsion treated material properties for structural design8-8

LIST OF FIGURES

Figure 2.1 Schematic overview of the ETB mix design process	2-4
Figure 2.2 Effect of cement content on CBR for G4 material	2-4
Figure 3.1 Backcalculated E-moduli at various HVS repetitions	3-5
Figure 3.2 Measured deflection basins at various repetitions.....	3-6
Figure 3.3 Design chart for ETB for subgrade modulus of 20 MPa (3 000 psi)	3-8
Figure 3.4 Fatigue criteria for emulsion treated material for 11% bitumen and 5% air voids by volume	3-9
Figure 3.5 Flow diagram for structural design of emulsion treated bases.....	3-14
Figure 3.6 Transfer function for shear failure for granular materials.....	3-16
Figure 3.7 Proposed design catalogue for emulsion treated materials by De Beer and Grobler (1994).....	3-18
Figure 3.8 Proposed design catalogue for emulsion treated materials by Theyse (1998)	3-19
Figure 4.1 Transfer function for granular materials	4-4
Figure 4.2 S-N curves for G1 to G6 materials at a terminal permanent strain of 20 000 $\mu\epsilon$	4-5
Figure 4.3 Comparison of the relationship between maximum tensile strain ratio (ϵ_s/ϵ_b) and number of strain repetitions to initiate effective fatigue cracking in cemented layers.....	4-8
Figure 4.4 Comparison of the fatigue criteria applicable to strongly cemented layers	4-9
Figure 4.5 Shift factor for cemented layers	4-11
Figure 4.5 Criteria for prediction of subgrade performance in Southern Africa	4-15
Figure 4.6 Emulsion treated materials relative to other materials	4-17
Figure 5.1 Typical set-up of the four point static beam test.	5-4
Figure 5.2 Typical Stress-Strain response measured during four-point beam test.	5-4
Figure 5.3 Typical result from the static triaxial test.....	5-6
Figure 5.4 Typical calculated results from a set of dynamic triaxial data	5-7
Figure 5.5 Overall view of the Heavy Vehicle Simulator	5-9
Figure 5.6 Test section layout for sections 410A4a and 410B4	5-10
Figure 5.7 Test section layout for section 412A4A.....	5-10
Figure 5.8 Influence of cement and net bitumen contents on the UCS	5-13
Figure 5.9 Influence of cement and net bitumen contents on the ITS	5-14
Figure 5.10 Influence of cement and net bitumen contents on the strain at break	5-17
Figure 5.11 Influence of cement and net bitumen contents on the stress at break	5-18
Figure 5.12 Influence of cement and net bitumen contents on the dissipated energy	5-18
Figure 5.13 Sample from laboratory (2 % cement, 1.8 % net bitumen), 32x magnification.....	5-19

Figure 5.14 Optical microscope images of emulsion treated materials with different net bitumen contents (0% cement)	5-19
Figure 5.15 $p_f - q_f$ diagram from static triaxial tests	5-22
Figure 5.16 M6hr stress circles representation of the stress ratio concept	5-23
Figure 5.17 Resilient modulus as a function of the various laboratory test variables	5-25
Figure 5.18 Resilient modulus vs. Bulk stress	5-25
Figure 5.19 Typical permanent deformation results as measured in a dynamic triaxial test	5-26
Figure 5.20 Influence of Relative Density, degree of saturation and stress ratio on the number of repetitions to 9 % plastic strain	5-27
Figure 5.21 Permanent deformation on HVS test sections as measured by the straight edge	5-29
Figure 5.22 Permanent deformation on HVS test sections as measured by the laser profilometer	5-29
Figure 5.23 Permanent deformation on HVS test sections as measured by the MDD module at 40 mm.	5-30
Figure 5.24 Maximum RSD elastic deflection per test section	5-31
Figure 5.25 Radius of curvature per test section	5-32
Figure 5.26 Deflection bowls per test section	5-32
Figure 5.27 MDD elastic in-depth deflections at MDD4 of test section 412A4 (40 kN test section).....	5-33
Figure 5.28 MDD maximum elastic deflection at 40 and 80 kN test loads.....	5-34
Figure 5.29 Final crack patterns	5-34
Figure 5.30 Test pit at section 410B4.....	5-35
Figure 5.31 Reduction of E-moduli of C3 material under trafficking	5-37
Figure 5.32 Back calculated E moduli for the different test sections	5-38
Figure 6.1 Tensile strain analysis	6-3
Figure 6.2 Schematic illustration of the initiation of cracks at the MDD at bottom of the layer	6-3
Figure 6.3 Horizontal tensile strains in the emulsion treated layer.	6-4
Figure 6.4 Life to crack initiation for ferricrete tested at HVS site near Vereeniging	6-5
Figure 6.6 Effective fatigue life for HVS tested emulsion treated material.	6-6
Figure 6.5 Reduction in stiffness with increase in load repetitions on HVS test sections.....	6-7
Figure 6.6 Effective fatigue life of an emulsion treated material	6-8
Figure 6.7 Confidence limits represented by a second function drawn parallel to the regression function.....	6-11
Figure 7.1 HVS permanent deformation model	7-2
Figure 7.2 Illustration of tensile strains and stresses developed in the linear elastic theory	7-3
Figure 7.3 M6hr circle with tensile minor principal stress	7-4
Figure 7.4 Adjusted M6hr circle with minor principal stress equals to zero	7-4

Figure 7.5 Contour plot of the stress ratio on the HVS pavement under 40 KN, 620 kPa dual wheel load.....	7-6
Figure 7.6 Contour plot of octahedral shear stress under a 40 kN, 620 kPa dual wheel load in a 250 mm thick emulsion treated layer.....	7-6
Figure 7.7 Recommended positions to calculate the critical Stress Ratio	7-7
Figure 7.8 Comparison between laboratory test results, HVS test results and foam bitumen study.....	7-8
Function 7.9 HVS transfer functions compared to foam bitumen model.....	7-9
Figure 7.10 HVS transfer functions compared to original laboratory data, shifted laboratory data and foam bitumen model.....	7-10
Figure 7.10 Transfer function for permanent deformation of emulsion treated materials.....	7-11
Figure 8.1 General behaviour of pavements.....	8-4
Figure 8.2 Illustration of different types of emulsion treated materials for structural design	8-5
Figure 8.3 Proposed Classification of emulsion treated materials.....	8-6
Figure 8.4 Effective fatigue transfer function for emulsion treated materials.....	8-10
Figure 8.5 Permanent deformation transfer function for emulsion treated materials	8-12
Figure 8.6 Calculating the ultimate pavement life for a pavement structure with emulsion treated layers.....	8-15
Figure 8.7 Structural design catalogue for ET1 emulsion treated base layers.....	8-16
Figure 8.8 Structural design catalogue for ET2 emulsion treated base layers.....	8-17
Figure 9.1 Influence of cement and net bitumen content on main engineering properties.....	9-2

LIST OF ABBREVIATIONS

AASHO	American Association of State Highway Officials
AASHTO	American Association of State Highway Transportation Officials
ASTM	American Standard Test Methods
CBR	California Bearing Ratio
COLTO	Committee of Land Transportation Officials
CSIR	Council for Scientific Industrial Research
CSRA	Committee of State Road Authorities
ETB	Emulsion treated base
GEMS	Granular emulsion mixes
GM	Grading modulus
HVS	Heavy Vehicle Simulator
ICL	Initial Consumption of Lime
ITS	Indirect Tensile Strength
LVDT	Linear Variable Displacement Transducer
MDD	Multi Depth Deflectometer
PI	Plasticity Index
SABITA	Southern Africa Bitumen and Tar Association
SAMPDP	South African Mechanistic Pavement Design Procedure
TRH	Technical Recommendations for Highways
UCS	Unconfined Compressive strength

LIST OF SYMBOLS

a'	structural coefficient for recycled layers used as base
a_1, a_2, a_3	AASTHO layer coefficients
B_V	Proportion of bitumen present in asphalt mix
c	Cohesion (kPa)
CDF	Cumulative damage factor (Miner's law)
c_{term}	Cohesion term
d	Thickness of asphalt layer (mm)
E	Modulus of elasticity (MPa)
e	natural logarithm = 2.718 281 828 46....
E_1	Elastic modulus of base layer (MPa)
E_2	Elastic modulus of subbase layer (MPa)
E_{bend}	Bending stiffness of beam (MPa)
E_i	Initial modulus of elasticity (MPa)
E_{bend}^i	Initial bending stiffness of beam (MPa)
FOS	Factor of safety
h_1	Thickness of base layer (mm or inches)
h_2	Thickness of subbase layer (mm or inches)
K	Constant indication moisture regime when calculating Factor of Safety
K_1, K_2	Constants describing stress sensitivity material
M_f	Final modulus (MPa)
M_R	Resilient modulus (MPa)
M_t	Modulus at specific time after construction @ 23°C (MPa)
N	Number of load repetitions
N_{c1}	Load repetitions to initiate crushing
N_{c2}	Load repetitions to advanced crushing
N_{eff}	Effective fatigue life

N_f	Number of load repetitions to failure
N_{ff}	Fatigue and fracture life
n_i	Damage of i^{th} load repetition
n_i	Number of load repetitions to crack initiation
N_{if}	Initial fatigue life
N_{PD}	Number of load repetitions to certain level of plastic strain
N_{std}	Number of load repetitions of standard wheel load to certain level of distress
N_t	Total number of allowable load repetitions
N_x	Number of load repetitions of wheel load to certain level of distress
Pen	Penetration of recovered bitumen
p_f	normal stress (kPa)
π	pi = 3.141 592 653 59...
P_{std}	Standard wheel load (kN)
P_x	wheel load (kN)
q_f	Shear stress (kPa)
RD	Relative density (%)
RF	Early cure reduction factor
S	Degree of saturation (%)
S	Sand equivalent value (#4 sieve to minus 200 mesh)
SF	Shift factor
SN	Structural number
SR	Stress ratio
t	Thickness of emulsion treated base layer (mm)
V_B	Bitumen content by volume (%)
V_V	Voids content (%)
σ_1^m	Maximum allowable major principal stress (kPa)
σ_1^a	Working or applied major principal stress (kPa)

σ	Applied stress from tri-axial test (kPa)
θ	Bulk stress (kPa)
α	Factor depending on amount of filler voids present in asphalt mix
ϕ	Friction angle (degrees)
ρ	relative density (lb/ft ³ or kg/m ³)
ε	Resilient strain measured (ε)
τ	Shear stress (kPa)
σ_1	Major principal stresses (kPa)
σ_2	Intermediate principal stress (kPa)
σ_3	Minor principal stresses (kPa)
ε_b	Strain at break ($\mu\varepsilon$)
σ_b	Stress at break (kPa)
σ_d	Deviator stress (kPa)
ε_i	Induced tensile strain due to loading ($\mu\varepsilon$)
ε_m	Tensile strain in asphalt mixture ($\mu\varepsilon$)
σ_{max}	Maximum stress (kPa)
ε_{mix}	Bending strain repeatedly applied to asphalt mixture ($\mu\varepsilon$)
ε_p	Permanent (plastic) strain (ε)
ε_t	Horizontal tensile strain ($\mu\varepsilon$)
σ_t	Vertical compressive stress on top of base layer \approx tyre contact pressure (kPa)
ϕ_{term}	Internal friction angle term (degrees)
ε_v	Vertical compressive strain ($\mu\varepsilon$)
σ_v	Vertical compressive strain (kPa)