

CHAPTER 8 THE STRUCTURAL DESIGN OF EMULSION TREATED MATERIALS

8.1 INTRODUCTION

The structural design of pavements is aimed at the protection of the subgrade by the provision of pavement layers in order to achieve a chosen level of service over a predetermined period. It considers factors of time, traffic loading, pavement materials, subgrade conditions, environmental details and economics. The main purpose of structural design is to obtain an objective rational estimate of the capacity of the pavement, with a certain level of confidence, to provide an acceptable service level without major structural distresses.

The TRH4:1996 (COLTO: 1996), South African Mechanistic Pavement Design Method, the Asphalt Institute method and the AASHTO design method are all methods that provide guidelines on the structural design of pavements. In South Africa the TRH4 and the South African Mechanistic Pavement Design Method are widely used in the design of new and rehabilitated pavements.

The models developed in this study will provide interim guidelines for the design of emulsion treated materials as pavement layers, using the principles of the TRH4 and the South African Mechanistic Pavement Design Method.

The TRH4 categorises roads into four categories. Category A roads are major interurban roads or interurban freeways that require a high level of service and reliability. Category B roads are interurban collectors, major rural roads and major industrial roads. These roads also require a high level of service and reliability. Category C roads are lightly trafficked rural and strategic roads, which have less traffic loading and require a lower level of service and reliability. Category D roads are light pavement structures, typically for rural access roads. These roads have a low traffic loading and require a low level of service. The four categories are summarised in Table 8.1.

Table 8.1 Definition of main road categories used in pavement design (COLTO: 1996, Jordaan: 1994)

ROAD CATEGORY				
	A	B	C	D
Description	Major interurban freeways and roads	Interurban collectors and major rural roads	Lifghtly trafficked rural roads, strategic roads	Light pavement structures, rural access roads
Importance:	Very important	Important	Less Important	Less important
Service Level:	Very high	High	Moderate	Moderate to low
TYPICAL PAVEMENT CHARACTERISTICS				
	RISK			
	Very Low	Low	Medium	High
Approximate design reliability	95	90	80	50
Equivalent traffic loading (E80/lane)	3 – 100 million over 20 years	0.3 – 10 million depending on design strategy	< 3 million depending on design strategy	< 1 million depending on design strategy
Typical pavement class	ES3 to ES100	ES1 to ES10	ES0.1 to ES3	ES0.1 to ES1
Daily traffic (e.v.u)	> 4 000	600 – 10 000	< 600	< 500
Construction riding quality: IRI (mm/m)	2.4 – 1.6	2.9 – 1.6	3.5 – 2.4	4.2 – 2.4
Terminal riding quality: IRI (mm/m)	3.5	4.2	4.5	5.1
Warning rut level (mm)	10	10	10	10
Terminal rut level (mm)	20	20	20	20
Area of road exceeding terminal condition (%)	5	10	20	50

Design traffic classes are divided into 7 groups depending on the number of standard 80 kN axles in the analysis period. A summary of the traffic classes is presented in Table 8.2.

Table 8.2 Traffic classes according to TRH4:1996

Traffic Class	Traffic loading range (E80's)
ES0.1	< 100 000
ES0.3	100 000 to 300 000
ES1	300 000 to 1 million
ES3	1 million to 3 million
ES10	3 million to 10 million
ES30	10 million to 30 million
ES100	30 million – 100 million

8.2 GENERAL PAVEMENT BEHAVIOUR

Pavement behaviour is a function of the initial construction composition of the pavement, the load carried by the pavement and the environment in which it operates. In addition to the as-built strength, pavement behaviour is also influenced by the behaviour of the materials in the various pavement layers. The type and behaviour of the material in the base layer of the pavement is of particular importance because it is close to the surface and distress in the base often reflects through to the surface of the road. It also has little protection in terms of material covering the layer and a relatively high quality and load-bearing strength is usually required from a base layer. The state of the materials in the pavement layers changes with time. The behaviour of pavements with different base layers differs slightly, but with a similar trend. The general behaviour is presented in Figure 8.2.

A detailed discussion of the behaviour of all the pavement materials can be found in the work of Jordaan (1994).

In general, a newly constructed pavement will have an initial phase where some densification will occur in the wheel tracks. This might not be the case with cemented and asphalt base pavements. Following this phase, the pavement will enter a stable phase during which little deformation or other distress occurs. The rate of increase in deformation, or other distresses, during this phase depends on the initial quality of the material. After the stable phase, the pavement will enter a phase where distresses and permanent deformation occur at an increasing rate. This may cause an increase in moisture content from water entering through cracks and without maintenance will result in failure of the layer.

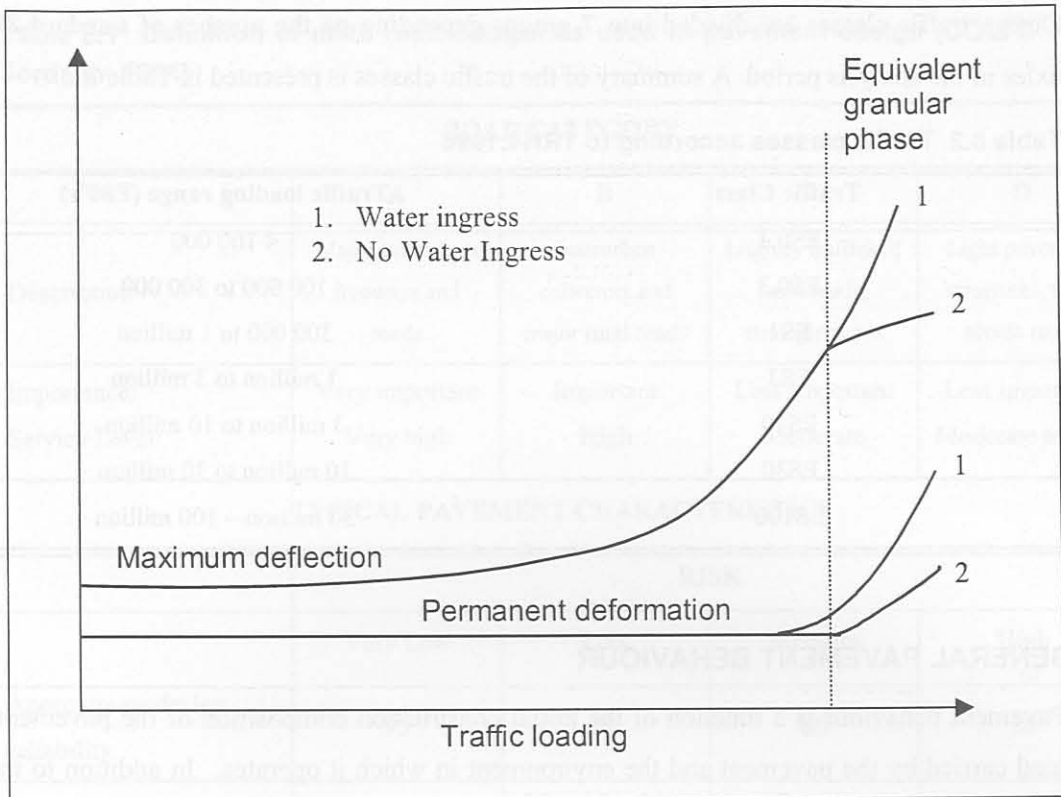


Figure 8.1 General behaviour of pavements (Freeme: 1983)

8.3 BEHAVIOUR OF EMULSION TREATED MATERIALS

The general behaviour of emulsion treated materials is similar to that of lightly cemented materials in the sense that emulsion treated materials also have a phased behaviour. As discussed in previous chapters, the first phase is a fatigue life phase similar to cemented materials, while the second phase is an “equivalent granular” phase, similar to granular unbound materials. The cement content of the emulsion treated material will determine the degree of resemblance to lightly cemented material. Higher cement contents will have behaviour similar to lightly cemented materials, while low cement contents will have either a high fatigue resistance or behaviour similar to granular material, depending on the net bitumen content.

In essence, the behaviour of emulsion treated material is a two-phase behaviour. The first phase being the fatigue life phase, which is characterised by a high resistance to permanent deformation and high elastic modulus. The second phase is known as the “equivalent” granular phase where the material behaves similarly to granular materials although it may still be physically intact. These different behaviour phases were discussed in detail in chapters 6 and 7.

8.4 MATERIAL CLASSIFICATION

In SABITA manual 21 (SABITA: 1999) emulsion treated materials are divided into two classes namely E1 and E2. This classification is based mainly on the material mix design. An E1 material would typically consist of parent materials of G1 to G3 or CTB quality materials with a residual bitumen content of less than 1 to 1.5 %. E2 type materials would typically consists of parent materials of G4 to G5 quality material with residual bitumen content of less than 1.8 %.

A new classification system for emulsion treated materials is proposed to take into account the influence of cement in the mix. Emulsion treated materials can be constructed with high or low cement content and with high or low net bitumen content. These variations have an effect on the strength and flexibility of the material. A classification system compatible with that of foam bitumen (Asphalt Academy: 2002) is proposed. Figure 8.2 gives an illustration of the four different combinations of emulsion treated materials.

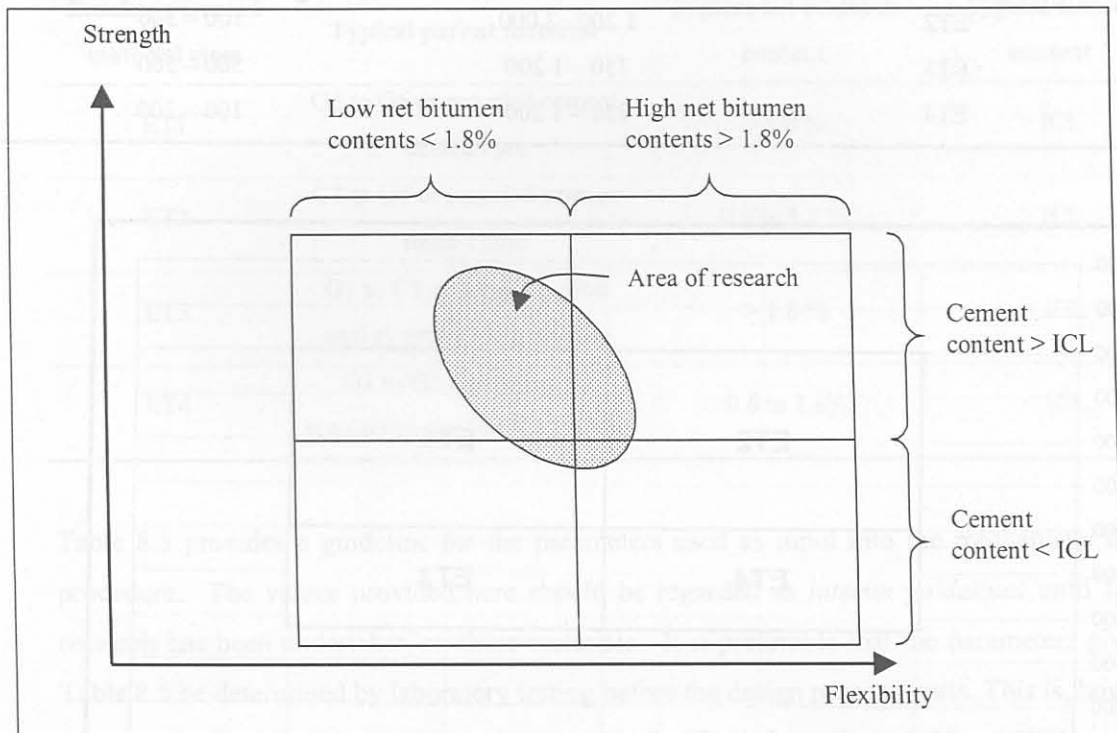


Figure 8.2 Illustration of different types of emulsion treated materials for structural design

The minimum Unconfined Compressive Strength (UCS) limits were set according to SABITA manual 21 (SABITA: 1999). The maximum UCS limits were selected by assuming that an emulsion treated material would not have maximum UCS values similar to that of a C4 lightly cemented material. The maximum value required for a C4 was then reduced by 1 000 kPa to obtain the maximum limit for emulsion treated materials. The above values were generated as

little research is available on desirable maximum allowable UCS for emulsion treated materials. A maximum limit is important to ensure that the layer is not built to such strength that the benefit of the emulsion in providing flexibility, is overshadowed by the cement in the mix.

Little information is available on the limits for the Indirect Tensile Strength (ITS) of emulsion treated material. Values of between 250 and 600 have been reported (Louw: 1997). Until further research provides better information, it is proposed that the guidelines used in foam bitumen be adopted. This may be applicable because of the similarity between foam bitumen and emulsion treated materials. The classification system and the UCS and ITS limits are presented in Figure 8.3 and Table 8.3.

Table 8.3 Proposed Classification of Emulsion treated materials

Material classification	UCS (kPa)	ITS (kPa) @ 23°C
ET1	1 200 – 2 000	300 – 500
ET2	1 200 – 2 000	100 – 300
ET3	750 – 1 200	300 – 500
ET4	750 – 1 200	100 – 300

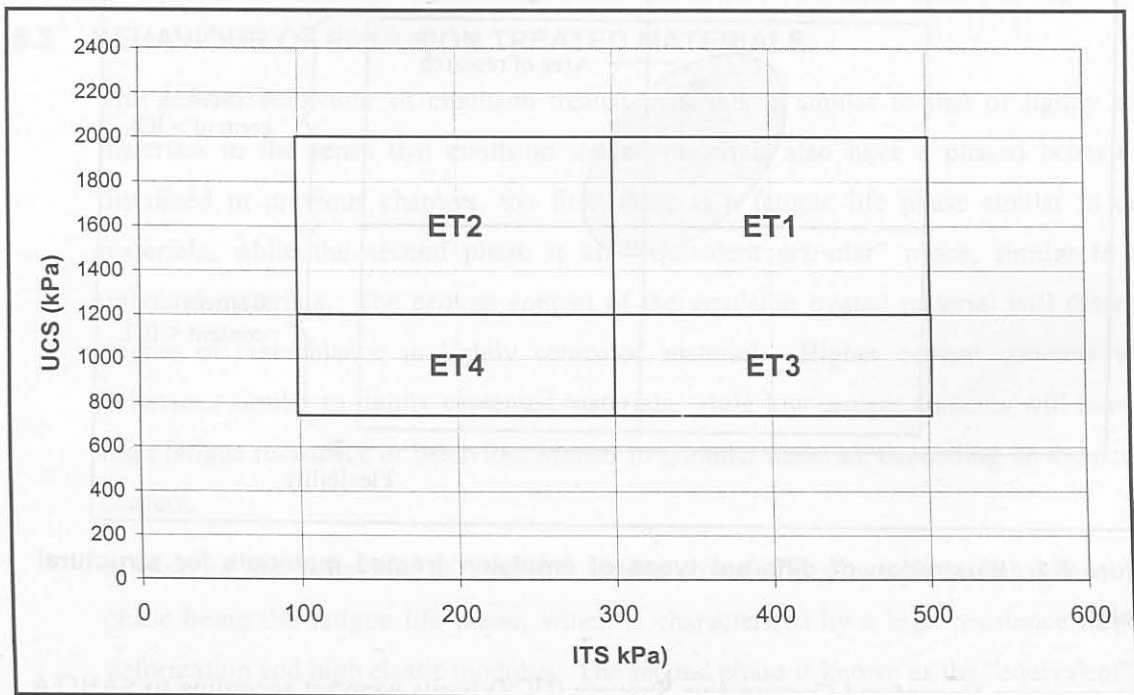


Figure 8.3 Proposed Classification of emulsion treated materials

Table 8.4 provides a summary of the typical composition of the different emulsion treated classes.

The different types of emulsion materials possible, provide the designer with a pavement structure which is either strong or flexible. The parent material available for emulsion treatment plays a role in the decision of the quantity of stabilising agent (cement, lime or emulsion) to be added, to obtain a predetermined level of performance. ET1 materials are therefore not necessarily superior to ET2 or ET3 materials, neither are ET4 materials only suitable for low volume roads. A G1 crushed stone material stabilised with no cement and 1.0 % bitumen emulsion, may be as good a product as stabilising a G4 material with 2 % cement and 3 % bitumen emulsion. In this case, the G1 stabilised material will be categorised as an ET4 material, while the G4 stabilised material will be categorised as an ET1 or ET3. The performance of materials which falls into the ET4 material class have not been researched and the structural design of these materials are excluded from this study. Experience (Bergh: 2001) has however shown that these material performed extremely well in practice.

Table 8.4 Typical composition of emulsion treated material per class

Emulsion treated material class	Typical parent material	Typical net bitumen content	Typical cement content
ET1	G3 to G6 or recycled cement treated base	> 1.8 %	> ICL
ET2	G3 to G6 or recycled cement treated base	0.6 to 1.8 %	> ICL
ET3	G1 to G5 or recycled good quality cement treated base	> 1.8 %	< ICL
ET4	G1 to G5 depending on requirements of traffic loading	0.6 to 1.8%	< ICL

Table 8.5 provides a guideline for the parameters used as input into the mechanistic design procedure. The values provided here should be regarded as *interim guidelines* until further research has been undertaken on these materials. It is preferable that the parameters given in Table 8.5 be determined by laboratory testing before the design process starts. This is, however, often expensive, time consuming and not practical. The information of C4 and EG5 materials is given for comparison only.

Initial stiffness: The initial stiffness is the elastic stiffness (elastic modulus) the material will have at the beginning of the fatigue life phase, i.e. just after construction. The initial stiffness is highly dependent on the cement stabilisation of the material and high cement content will increase the value.

Terminal stiffness: The terminal elastic stiffness is the stiffness the material will converge to when it reaches the end of its fatigue life. A value of 500 MPa has been backcalculated for the

material tested in this study, but the value will vary depending on the quality of the parent material and the amount of stabilisation. Better quality parent materials will have higher terminal stiffness values, while lower quality material will have lower stiffness values. The range of values proposed are a typical range in which terminal stiffnesses could lie and were estimated from the type of parent materials that would typically be used in emulsion stabilisation. The designer should familiarise himself with the parent material and select an appropriate stiffness accordingly.

Table 8.5 Proposed emulsion treated material properties for structural design

Property	ET1	ET2	ET3	ET4	C4	EG5
Initial Stiffness (MPa)	1 200 – 2 700 (1 800)	1 200 – 2 700 (1 800)	N/A ^(*)	N/A ^(*)	1 500 ^(a)	-
Terminal stiffness (MPa)	300 – 600 (500)	300 – 600 (500)	N/A ^(*)	N/A ^(*)	-	200 ^(a)
Poissons ratio	0.35 ^(b)	0.35 ^(b)	0.35 ^(b)	0.35 ^(b)	0.35	0.35
Strain at break ($\mu\epsilon$)	230	145	N/A ^(*)	N/A ^(*)	145 ^(a,c)	-
Cohesion (c) (kPa)	200 – 300 (250)	200 – 300 (250)	N/A ^(*)	N/A ^(*)	283 - 502 ^(d) 335 ^(e)	40
Friction angle (ϕ)	50°	50°	N/A ^(*)	N/A ^(*)	-	43°
c-term ^(g)	1 374	1 374	N/A ^(*)	N/A ^(*)	-	147 ^(a,f)
ϕ -term ^(h)	6.55	6.55	N/A ^(*)	N/A ^(*)	-	3.43 ^(a,f)

^(*) No research data available

^(a) Jordaan (1994)

^(b) Assumed value, not measured

^(c) de Beer (1985)

^(d) de Beer (1990)

^(e) Long et al (2001)

^(f) Moderate moisture condition

$$^{(h)} \phi_{term} = K \left(\tan^2 \left(45 + \frac{\phi}{2} \right) - 1 \right) \quad (8.1)$$

$$^{(i)} c_{term} = 2.K.c. \tan \left(45 + \frac{\phi}{2} \right) \quad (8.2)$$

Note. Values in brackets used in development of the design catalogue (Appendix F)

Strain at break: The strain at break gives an indication of the flexibility of the material. It is highly dependent on the cement and bitumen content. High bitumen content increases the value while an increase in cement content decreases the value. ET3 and ET4 materials should have a higher strain at break than ET1 and ET2 materials because of its lower cement content. ET1 and ET3 materials, however, would have a higher strain at break over ET2 and ET4 materials, because of their higher bitumen content. The values given in Table 8.5 are the average value expected for the specific type of emulsion treated material.

Cohesion and Friction angle: The cohesion and friction angle is the shear strength parameters, which determines the permanent deformation behaviour of the emulsion treated materials in the second behaviour phase, i.e. the “equivalent granular” phase. From the laboratory study, as well as studies by Maree (1978, 1982) and de Beer (1989), the friction angle is dependent on the parent material and is not sensitive to the addition of stabilising agents. A typical friction angle for emulsion treated materials is proposed in Table 8.5, which does not differ between the different types of emulsion treated materials. The cohesion is much more dependent on the addition of stabilising agents than the friction angle. From the laboratory study the addition of emulsion to a cemented material did not change the cohesion significantly. A typical range of values are proposed from the results of the laboratory study and the work done by Otte (1972) and De Beer (1989) on cemented materials.

8.5 MECHANISTIC ANALYSIS OF EMULSION TREATED PAVEMENT

8.5.1 Loading

The same principles as in TRH4 and in the South African Mechanistic Pavement Design Method apply. The load is a 40 kN dual wheel load with a tyre pressure of 620 kPa. The reason that the tyre pressure is 620 kPa is that it gives a uniform load contact area. That is also the value the transfer functions were calibrated for. The loaded area is assumed to be circular.

8.5.2 Layer thickness

The layer thickness of an emulsion treated material layer may vary between 125 mm and 300 mm. It does not seem practical to build a layer thinner than 125 mm because of construction tolerances, while layers thicker than 300 mm may be expensive and difficult to compact.

8.5.3 Mechanistic modelling of pavement behaviour

The mechanistic analysis and design procedure proposed in this study only considers emulsion treated materials. Other materials are discussed in the South African Mechanistic Pavement Design Method (Jordaan: 1994, Theyse et al 1996).

A pavement with an emulsion treated material should be analysed in two phases. The first phase being the fatigue life phase and the second phase the “equivalent” granular phase.

Fatigue

Fatigue cracking is primarily the result of cumulative damage caused by the bending of the layer under traffic loading. The horizontal tensile strain in an emulsion treated layer is used to determine the fatigue life of the pavement. The fatigue life is defined as the number of load repetitions until the elastic modulus reduces to a value of about 500 MPa or 25% of the initial stiffness. The fatigue criteria for the different road categories are as follows:

$$\text{Category A: } N_{f_A} = 10^{7.9183 - 1.2775 \left(\frac{\epsilon_t}{\epsilon_b} \right)} \quad (8.3a)$$

$$\text{Category B: } N_{f_B} = 10^{8.0331 - 1.2775 \left(\frac{\epsilon_t}{\epsilon_b} \right)} \quad (8.3b)$$

$$\text{Category C: } N_{f_C} = 10^{8.1747 - 1.2775 \left(\frac{\epsilon_t}{\epsilon_b} \right)} \quad (8.3c)$$

$$\text{Category D: } N_{f_D} = 10^{8.5066 - 1.2775 \left(\frac{\epsilon_t}{\epsilon_b} \right)} \quad (8.3d)$$

where: N_f = Number of load repetitions to end of fatigue life

ϵ_t = Maximum tensile strain at bottom of layer

ϵ_b = Strain at break

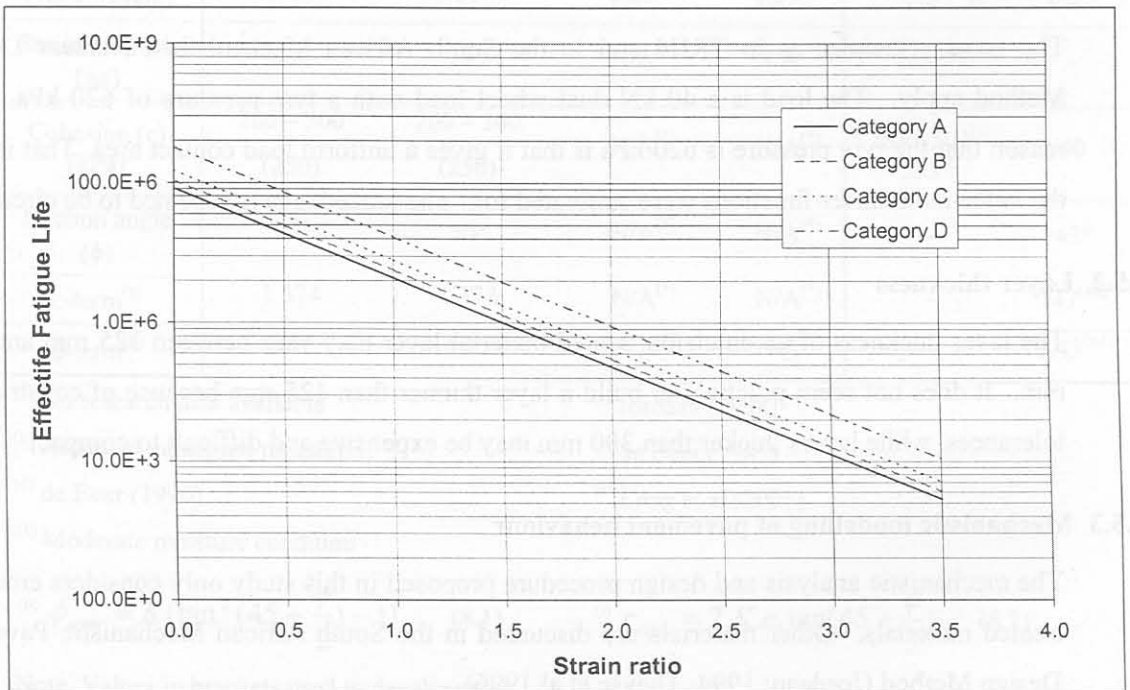


Figure 8.4 Effective fatigue transfer function for emulsion treated materials.

The maximum horizontal strain is not always at the bottom of the layer, and may be somewhere within the layer. Jordaan (1988) provided a procedure to test whether the maximum tensile strain is at the bottom of the layer.

The maximum horizontal tensile strain is at the bottom of the layer when:

$$\left(\frac{E_3}{E_2} \right)^2 h_c < K \quad (8.4)$$

$$\text{with: } h_c = h_1 \left(\frac{E_1}{E_3} \right)^{\frac{1}{3}} + h_2 \left(\frac{E_2}{E_3} \right)^{\frac{1}{3}} \quad (8.5)$$

where: E_1 = Elastic modulus of the asphalt layer (MPa)

E_2 = Elastic modulus of the emulsion treated layer (MPa)

E_3 = Elastic modulus of the supporting subbase layer (MPa)

h_1 = thickness of the asphalt layer (mm)

h_2 = thickness of the emulsion treated base layer (mm)

K = constant = 128

Procedure

- i) Determine the initial elastic properties of all pavement layers
- ii) Select an appropriate effective elastic modulus for the emulsion treated material from the recommended ranges in Table 8.5.
- iii) Use the modulus for all the pavement layers as determined in (i) and (ii) to determine the pavement response using an appropriate computer program
- iv) Determine whether the maximum tensile strain is at the bottom of the layer, using the procedure proposed by Jordaan (1988) described above. If not, a more detailed analysis of the layer is required.
- v) Determine the strain at break either from laboratory testing or using the guidelines in Table 8.5.
- vi) Use the appropriate transfer function for the category of road from Equations 8.3a to 8.3d to determine the effective fatigue life of the layer.

Permanent deformation (“equivalent granular” phase)

In the second phase the emulsion treated layer will be more susceptible to deformation. The stress state in the layer determines the permanent deformation behaviour of the layer. The failure criteria to 20 mm deformation on the surface for the different road categories is as follows:

$$\text{Category A: } \log N_{PD_A} = \left(\frac{54.005}{t} + 4.4736 \right) * (SR + 0.0664)^{-0.2313} \quad (8.6a)$$

$$\text{Category B: } \log N_{PD_B} = \left(\frac{54.005}{t} + 4.5389 \right) * (SR + 0.0664)^{-0.2313} \quad (8.6b)$$

Category C:
$$\log N_{PD_C} = \left(\frac{54.005}{t} + 4.6775 \right) * (SR + 0.0664)^{-0.2313} \quad (8.6c)$$

Category D:
$$\log N_{PD_D} = \left(\frac{54.005}{t} + 5.0213 \right) * (SR + 0.0664)^{-0.2313} \quad (8.6d)$$

where: N_f = Number of load repetitions to 20 mm deformation on surface

SR = Critical Stress ratio

t = thickness of the emulsion treated layer in mm.

$$SR = \frac{\sigma_1^a - \sigma_3}{\sigma_3 \left[\tan^2 \left(45^\circ + \frac{\phi}{2} \right) - 1 \right] + 2.c. \tan \left[45^\circ + \frac{\phi}{2} \right]} \quad (8.7)$$

or
$$SR = \frac{\sigma_1^a - \sigma_3}{\sigma_3 \cdot \phi_{term} + c_{term}} \quad (8.8)$$

where: SR = Stress ratio

ϕ = friction angle (measured in laboratory)

c = cohesion (kPa) (measured in laboratory)

ϕ_{term} = friction angle term from Table 8.5

c_{term} = cohesion term from Table 8.5

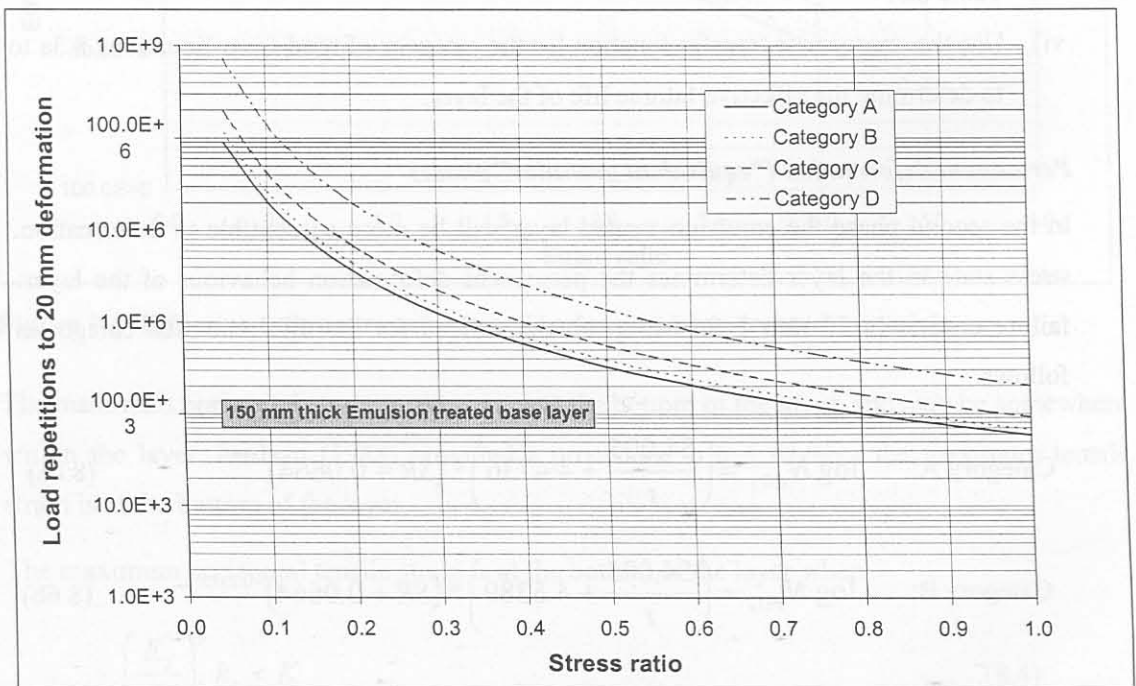


Figure 8.5 Permanent deformation transfer function for emulsion treated materials

Procedure

- i) Determine the initial elastic properties of all pavement layers in the second phase.
- ii) Select an appropriate effective elastic modulus for the emulsion treated material in its second phase (“equivalent” granular) from the recommended ranges in Table 8.5.
- iii) Use the modulus for all the pavement layers as determined in (i) and (ii) to determine the pavement response at the positions indicated in section 7.5.1 using an appropriate computer program
- iv) Use the procedure in section 7.5.1 to shift the minor principal stress if it is tensile.
- v) Calculate the stress ratio using Equation 8.7 or 8.8 by using the recommended values in Table 8.5, at the proposed positions as indicated in section 7.5.1.
- vi) Use the appropriate transfer function for the category of road from Equations 8.6a to 8.6b to calculate the bearing capacity of the layer to 20 mm of deformation on the surface.

The total life of the emulsion treated layer is the sum of the fatigue life and the bearing capacity to 20 mm deformation:

$$N = N_f + N_{PD} \quad (8.9)$$

Pavement life phases and residual life concept

The concept of pavement life phases has been introduced in the previous section. The phases are caused by changes taking place in pre-dominantly the emulsion treated layers in the pavement structure. The modulus of an emulsion treated layer is modelled as a constant value for the duration of a particular phase with a sudden change at the end of each phase.

The stresses and strains calculated during one phase, are not valid during the following phase. A structural analysis is therefore done for each phase with the applicable reduced moduli for the emulsion treated layer. The stresses and strains calculated for each phase will yield a predicted layer life for each layer during each phase. The transfer functions used for pavement design were developed for an initial condition of no distress. After phase 1, the predicted layer life for both phase 1 and 2 therefore becomes invalid but by combining the two values, an ultimate layer life may be calculated.

Consider the situation in Figure 8.6 where the layer life for each layer has been predicted for phase 1. At the end of phase 1, the modulus of the emulsion treated layer is suddenly reduced, resulting in higher stress/strain conditions in the other layers similar to an increase in loading on the pavement. The remaining part of the phase 1 predicted layer life for the other layers, or the residual life of the other layers is then reduced due to the increased stress conditions. The method assumes that the rate of decrease in the residual life of the other layers during the second phase, is equal to the ratio of the phase 1 predicted layer life to the phase 2 predicted

layer life for a particular layer, similar to a load equivalency factor. The only exception is the emulsion treated layer, which will start with a clean sheet for the second phase because there is a change in material state and therefore terminal condition. The predicted equivalent granular layer life for the original cemented layer will therefore be allocated to the emulsion treated layer in total for the second phase. Also note that if the top layer is a surfacing layer such as a surface seal or thin asphalt layer, then the predicted layer life for the top layer will not affect the ultimate pavement life. The reason for this is that surface maintenance should be done at regular intervals and it is not possible to design the thin asphalt surfacing layers for the total structural design life of the pavement structures, especially for high design traffic classes. The ultimate pavement life is calculated as the sum of the duration of phase 1 and the minimum adjusted residual life for phase 2 or the phase 2 predicted equivalent granular layer life for the original emulsion treated layer whichever is the smallest.

The process is extended along similar principles for a three phase analysis of a pavement structure incorporating an emulsion treated and cement-treated layers.

8.6 DESIGN CATALOGUE

A design catalogue, based on the mechanistic-empirical functions developed in this study is presented in Figures 8.7 and 8.8. The catalogue includes most of the factors that have to be considered by the designer. These include the road category and the design traffic loading over the design period. It should be used as an interim guideline and should not take precedence over the experience of the practitioner. The catalogue was, however, compared to other published catalogues on emulsion treated materials (de Beer and Grobler: 1994, Theyse: 1998). The pavement structures presented here are lighter than the pavement structures proposed by de Beer and Grobler (1994). This catalogue, however, agrees well with the catalogue proposed by Theyse (1998).

The catalogue allows the use of seals on roads with low design traffic volumes. It does not include practical considerations such as drainage, compaction or pavement cross-section. These aspects should be considered according to the TRH4 (COLTO: 1996).

The catalogue provides the use of ET1 and ET2 types of emulsion treated materials. No catalogue for ET3 and ET4 types of materials was developed.

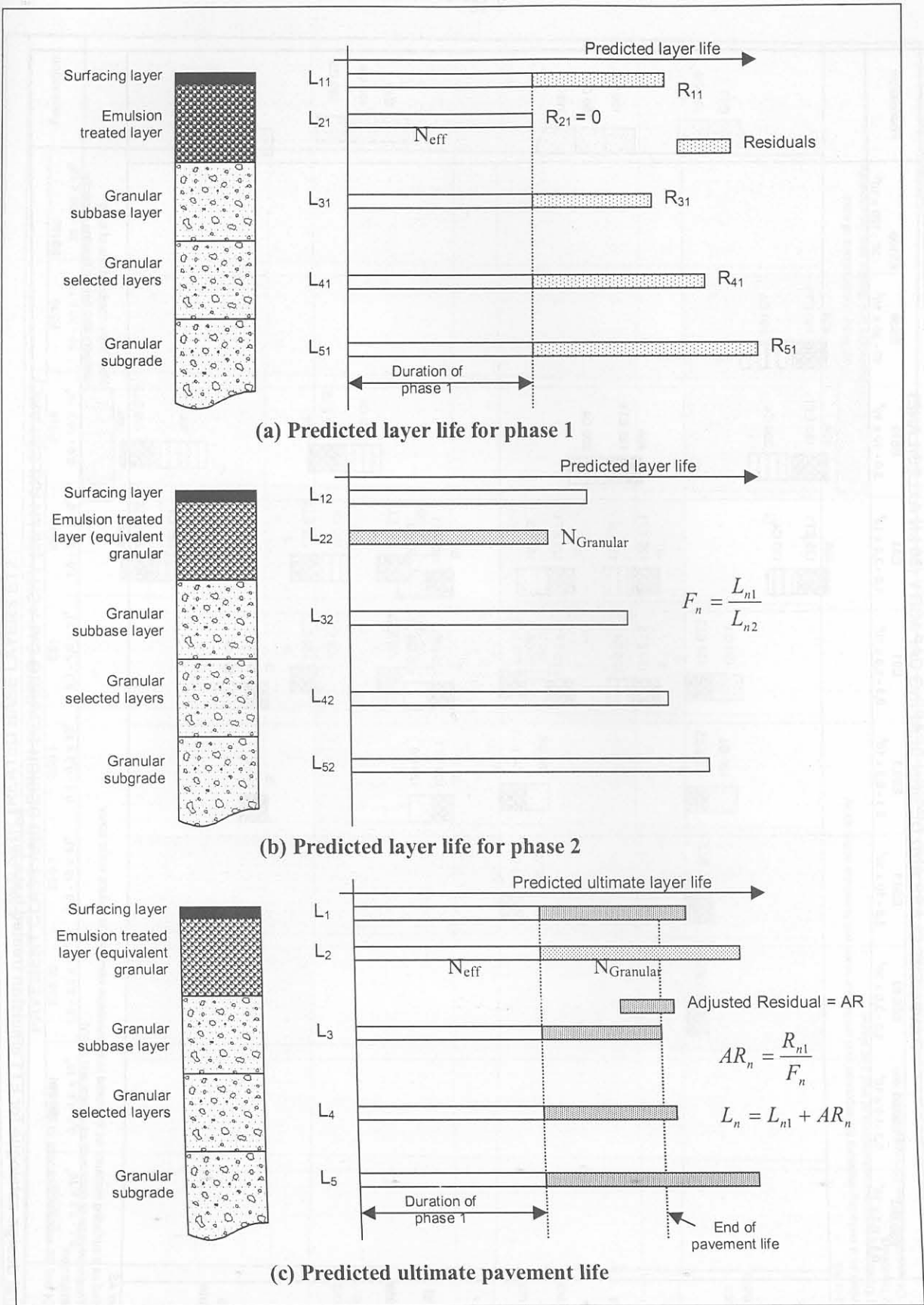


Figure 8.6 Calculating the ultimate pavement life for a pavement structure with emulsion treated layers

EMULSION TREATED BASE LAYERS ET1											
ROAD CATEGORY	PAVEMENT CLASS AND DESIGN BEARING CAPACITY (80 kN AXLES/LANE)										Foundation
	ES0.003 0,1 - 0,3 x 10 ⁴	ES0.01 0,3 - 1,0 x 10 ⁴	ES0.03 1,0 - 3,0 x 10 ⁴	ES0.1 3,0 - 10 x 10 ⁴	ES0.3 0,1 - 0,3 x 10 ⁶	ES1 0,3 - 1,0 x 10 ⁶	ES3 1,0 - 3,0 x 10 ⁶	ES10 3,0 - 10 x 10 ⁶	ES30 10 - 30 x 10 ⁶	ES100 30 - 100 x 10 ⁶	
A: Major interurban freeways and roads. (95% approximate design reliability)											
B: Interurban collectors and major rural roads. (90% approximate design reliability)						 	 				
C: Lightly trafficked rural roads and strategic roads. (80% approximate design reliability)											
D: Lightly pavement structures, rural access roads. (80% approximate design reliability)											

Symbol A denotes AG, AC or AS
 AO, AP may be recommended as a surfacing measure for improved skid resistance when wet to reduce water spray
 S denotes Double Surface Treatment (seal or combinations of seal and slurry)
 S1 denotes Single Surface Treatment
 * is Seal is used, increase C4 and G5 subbase thickness to 200 mm

Most likely combinations of road category and design bearing capacity

Figure 8.7 Structural design catalogue for ET1 emulsion treated base layers

ROAD CATEGORY	EMULSION TREATED BASE LAYERS ET2										Foundation
	PAVEMENT CLASS AND DESIGN BEARING CAPACITY (80 kN AXLES/LANE)										
	ES0.003 0,1 - 0,3 x 10 ⁴	ES0.01 0,3 - 1,0 x 10 ⁴	ES0.03 1,0 - 3,0 x 10 ⁴	ES0.1 3,0 - 10 x 10 ⁴	ES0.3 0,1 - 0,3 x 10 ⁶	ES1 0,3 - 1,0 x 10 ⁶	ES3 1,0 - 3,0 x 10 ⁶	ES10 3,0 - 10 x 10 ⁶	ES30 10 - 30 x 10 ⁶	ES100 30 - 100 x 10 ⁶	
A: Major interurban freeways and roads. (95% approximate design reliability)											
B: Interurban collectors and major rural roads. (90% approximate design reliability)					 	 					
C: Lightly trafficked rural roads and strategic roads. (80% approximate design reliability)											
D: Lightly pavement structures, rural access roads. (80% approximate design reliability)											

Symbol A denotes AG, AC or AS
 AO, AP may be recommended as a surfacing measure for improved skid resistance when wet to reduce water spray
 S denotes Double Surface Treatment (seal or combinations of seal and slurry)
 S1 denotes Single Surface Treatment
 * is Seal is used, increase C4 and G5 subbase thickness to 200 mm

Most likely combinations of road category and design bearing capacity

Figure 8.8 Structural design catalogue for ET2 emulsion treated base layers

8.7 REFERENCES

- Asphalt Academy, 2002, *The Design and Use of Foamed Bitumen Treated Materials*, Interim Technical Guideline TG2, Asphalt Academy, Pretoria, South Africa.
- Bergh AO, 2001, *Personal correspondence and communication*, Pretoria, South Africa.
- Committee of Land Transportation Officials (COLTO), 1996, *Structural design of flexible pavements for interurban and rural roads*, Draft TRH4:1996, Department of Transport, Pretoria, South Africa.
- Committee of State Road Authorities (CSRA), 1987, *Guidelines for Road Construction Materials*, TRH14:1987, Department of Transport, Pretoria.
- De Beer M and Grobler JE, 1993, *ETB': Heavy Vehicle Simulator (HVS) Evaluation of the Heilbron Sections*, South African Roads Board, Service Contract Report PR92/2/1, Pretoria, South Africa.
- De Beer M, 1985, Behaviour of cementitious subbase layers in bitumen base road structures in South Africa, MEng dissertation, University of Pretoria, Pretoria.
- De Beer M, 1989, Aspects of the design and behaviour of road structures incorporating lightly cemented layers, PhD Thesis, University of Pretoria, Pretoria.
- Freeme et al. 1983, *Evaluation of pavement behaviour for major rehabilitation of roads*, Technical Report RP/19/83, CSIR, Pretoria, South Africa.
- Jordaan GJ, 1988, *Analysis and developments of some pavement rehabilitation design methods*, PhD thesis, University of Pretoria, Pretoria, South Africa.
- Jordaan GJ, 1994, *The South African Mechanistic Pavement Rehabilitation Design Method*, Department of Transport, Research Report RR91/242, Pretoria, South Africa.
- Otte E, 1972, *Die Spannings en Vervormingseienskappe van Sementgestabiliseerde Materiale*, MSc(Eng) dissertation, University of Pretoria, Pretoria, South Africa.
- Long FM and Theyse HL, 2001, *Laboratory testing for the HVS Sections on Road P243-1*, Contract Report CR-2001/32, Transportek, CSIR, Pretoria, South Africa.
- Louw L, 1997, *ETB mix design: Summary of best practises*, Contract Report CR-96/079, CSIR Transportek, Pretoria, South Africa.
- Maree JH, 1978, *Ontwerpparameters vir klipslag in plaveisels*, MEng dissertation, University of Pretoria, Pretoria, South Africa.
- Maree JH, 1982, *Aspekte van die ontwerp an gedrag van padplaveisels met korrelmateriaalkroonlae*, PhD Thesis, University of Pretoria, Pretoria, South Africa.

SABITA, 1999, *ETB: The design and use of emulsion treated bases*, Manual 21, SABITA, Cape Town, South Africa.

Theyse HL, 1998, *Towards guidelines on the structural design of pavements with emulsion treated layers*, Transportek, CSIR, (CR-97/045), Pretoria, South Africa.

From the literature study, it is clear that mix design procedures for emulsion treated materials are well established and researched, but do not provide enough input into the structural design and analysis process. This could be because no existing structural design method recognises the difference in emulsion treated material mixes. Structural design procedures are available and are widely used. A number of structural design methods for the structural design of emulsion treated materials exist. Most of these methods are empirical and focus on higher net bitumen content mixes. Mixes with high bitumen content are, however, not always economical in South Africa. Design methods on emulsion treated materials with lower net bitumen content are based on the behaviour of similar materials.

The objective of this study was to define the stress-strain behaviour and failure criteria of pavement layers treated with bitumen emulsion and to develop design equations for the relative mode of failure to any material. From the laboratory and Heavy Vehicle Massing (HVM) study, it was possible to define the life cycle behaviour and failure criteria, as well as a structural design procedure was developed for these types of materials.

9.1 CONCLUSIONS

- The amount and net bitumen content have an influence on the important engineering properties. If the amount of bitumen increases, the strength of the material increases but the flexibility decreases. An increase in net bitumen content will increase the flexibility but reduces the strength up to a point where the strength will start to increase again. The behaviour will then be visco-elastic similar to that of asphalt materials. Figure 9-1 illustrates this concept.
- The stiffness of the material depends on three parameters. These include the quality of the parent material, the cement content and the bitumen content. Stiffness values are expected to range between 1 000 MPa and 1 700 MPa depending on these parameters. This study includes only materials with net bitumen content of between 0.6 and 1.0 % and cement content between 1 and 2 %.