APPENDIX E

Technical Memorandum

Updating Bituminous Stabilized Materials Guidelines: Mix Design Report, Phase II

Task 5:

Advanced Classification System for Cold Mixes based on Repeated Load Permanent Deformation Tri-axial Test, Part I

AUTHORS:

KJ Jenkins
LJ Ebels

1. BACKGROUND AND INTRODUCTION

1.1. Terms of Reference

Researchers in the field of pavement engineering first started to focus their attention on characterising the permanent deformation behaviour of granular pavement materials using the tri-axial test during the early 1960's (Haynes and Yoder, 1962). Barksdale (1972) and Francken (1977) provided more insight into the behaviour of pavement materials under repeated loading in the permanent deformation tri-axial test during the 1970's. Especially the General Permanent Deformation Law developed by Francken (1977) provided a basis for later work in the same field on unbound and (bitumen) stabilised materials (Huurman, 1997; Jenkins, 2000; Niekerk, 2002 and Ebels, 2008).

Until now, the philosophy of the structural performance of bitumen stabilised material in South Africa is largely based on the approach adopted in the South African Mechanistic Design Method for cement stabilised materials. This also formed the basis for the analysis of structural performance of foamed bitumen stabilised materials in the current TG2 Guideline (Asphalt Academy, 2002). The structural analysis in this guideline is a two-phase approach. Firstly, a phase of stiffness reduction of the stabilised material takes place that is associated with fatigue. The second phase of is one of accumulation of permanent strain in the stabilised material that is associated with shear deformation. The stress ratio concept plays an important role in the latter phase.

Whether or not the two-phased structural analysis approach is appropriate for BSM's is not the topic of this task. Reference is however made to Ebels et al. (2005), Ebels and Jenkins (2007) and Ebels (2008) in which concerns are raised that in the current structural design philosophy the importance of fatigue of BSM's is overestimated and that the actual performance of BSM's is more related to shear strength. Mix design and structural design should accordingly focus more on shear strength of BSM's and the characterisation of BSM's behaviour associated with shear deformation.

In light of the above, this task is concerned with establishing reliable models for the permanent deformation of BSM's. The repeated load (dynamic) tri-axial test is used to this extent. The models are largely based on the General Permanent Deformation Law as originally developed by Francken (1977).

1.2. Task Objectives

In the Project Proposal (PP/2005/09/c) for Phase II of Updating Bituminous Stabilized Materials Guidelines the objectives of Task 5 were listed as follows:

- Gather all data available for cold mix tests from dynamic permanent deformation tri-axial procedures ($N-\varepsilon$). Some of the data should be gathered from the CSIR. No additional testing is envisaged during this phase.
- Analyse critical stress ratios and their link to performance estimation
- Identify the composition of cold mixes that require further investigation to fill the gaps in the current level of knowledge
- Establish a preliminary classification system using the limited data that is available

2. GENERAL PERMANENT DEFORMATION BEHAVIOUR

2.1. Phases of permanent deformation

Permanent deformation is believed to occur in three phases. During the first phase the accumulation of permanent deformation takes initially place at a fast rate. This can mainly be attributed to bedding-in, seating of the loading plates and initial permanent strain due to densification. The deformation during this initial phase follows a hyperbolic curve. This mostly takes place during the first 20,000 load repetitions. Afterwards the rate of deformation starts to reduce. The first phase can, however, last up to 200,000 load repetitions or even more depending on the type of mix and the applied loading. An extreme cases were observed by Ebels (2008) for BSM mixes which consist for 75 % out of RAP and for which 4 % plastic strain (an end-condition limit in the permanent deformation tri-axial test) was reached after approximately 500,000 load repetitions at a relatively high stress ratio of 0.45, but where the permanent deformation accumulation was still following the trend of the initial phase.

The second phase is characterised by a constant rate of deformation. The accumulation of permanent deformation is more or less linear with respect to the number of load repetitions. The third phase is one of accelerated accumulation of permanent deformation due to tertiary flow. The third phase starts at the so-called flow-point, which is the number of load repetitions at which the strain accumulation rate is minimal. Up until the flow point the rate of strain accumulation reduces, while after the flow point the rate of strain accumulation accelerates. During the third phase the material may be considered to be failing in shear under repeated loading.

The number of load repetitions at which the flow point occurs cannot easily be predicted, as tertiary flow may initiate quite unexpectedly. For some of the tests conducted at the Stellenbosch University this transition took place after a number of load repetitions varying from 100,000 to 500,000 following a second phase with a stable and low rate of permanent deformation accumulation.

2.2. General Permanent Deformation Law

The formula which describes the permanent deformation behaviour as shown in Equation E-1 is referred to here as the General Permanent Deformation Law. The original formula was developed by Francken (1977) using time as the independent variable. This was later adjusted by Huurman (1997) to the number of load repetitions *N*, who also modelled the stress dependency of the model parameters *A*, *B*, *C*, and *D* as a function of the principal stress ratio. This was further adjusted to its current format as adjusted by Jenkins (2000) and van Niekerk (2002) who determined that the stress dependency in case of coarser grained materials can be better correlation with the deviator stress ratio.

$$\varepsilon_p = A \cdot \left(\frac{N}{1000} \right)^B + C \cdot \left(e^{D \cdot \frac{N}{1000}} - 1 \right) \qquad \text{Eq. E} - \quad 1$$

The first term of this model describes the linear part (on a log-log scale) of the permanent deformation curve and is characterised by the parameters A and B. The second term in Equation E-1 describes the tertiary flow part and is characterised by the parameters C and D. To illustrate the effect of these four model parameters (A to D) Ebels (2008) developed a series of graphs which are shown in Figure E-1 to Figure E-4, whereby in each of them only one parameter is changed. The default values for the four parameters used in the graphs below are A = 0.2 ; B = 0.3 ; C = 0.1 and D = 0.001. The permanent deformation curve described by these default coefficients is shown in bold the graphs below. These default parameter values are realistic and more or less average values found for the BSM mixes tested by Ebels (2008).

The scale of the axes of the graphs in Figure E-1 to Figure E-4 has been extended beyond realistic values (*i.e.* beyond 10^6 load repetitions) in order to be able to clearly demonstrate the effect of the various coefficients. Realistic values of permanent strain are limited to about 5 %, while values of *N* should not be extended much beyond 10^6 (none of the tests described in this study were extended beyond 10^6 load repetitions).

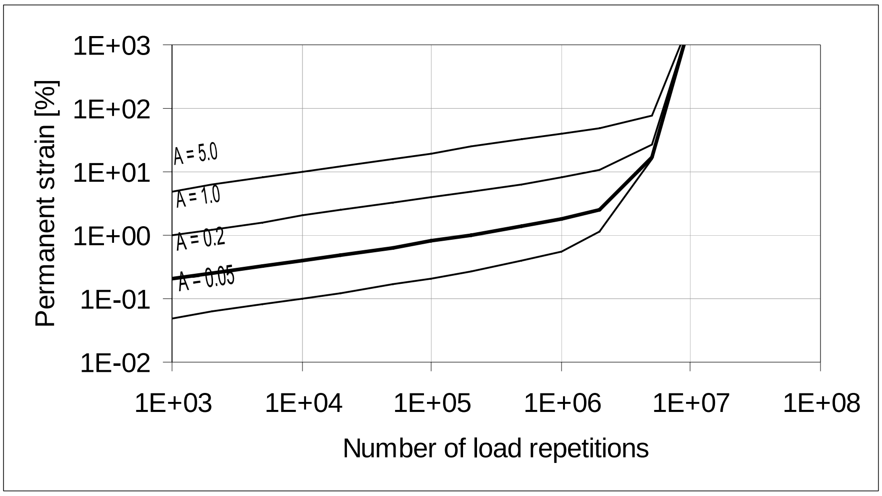


Figure E-1: The effect of changing model parameter A on the PD curve (Ebels, 2008)

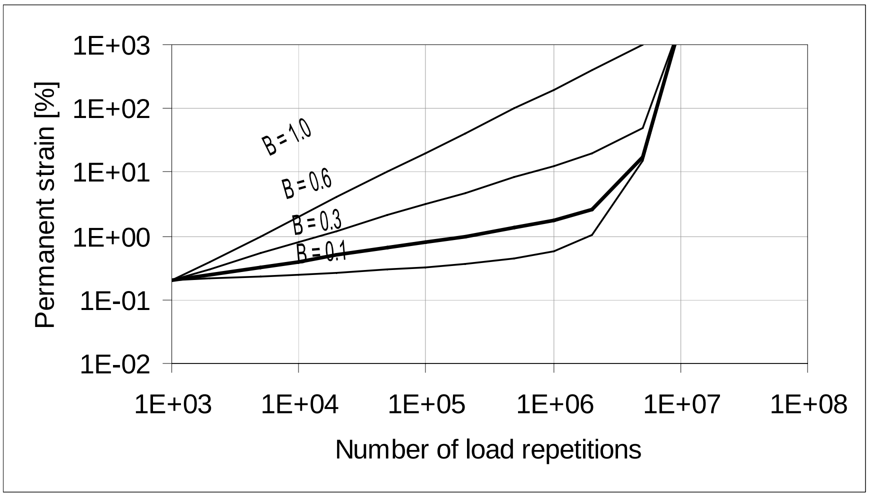


Figure E-2: The effect of changing model parameter B on the PD curve (Ebels, 2008)

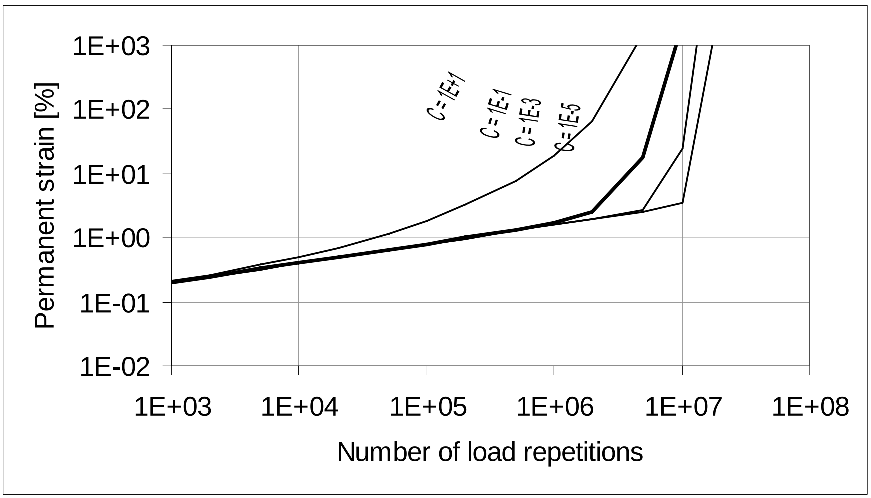


Figure E-3: The effect of changing model parameter C on the PD curve (Ebels, 2008)

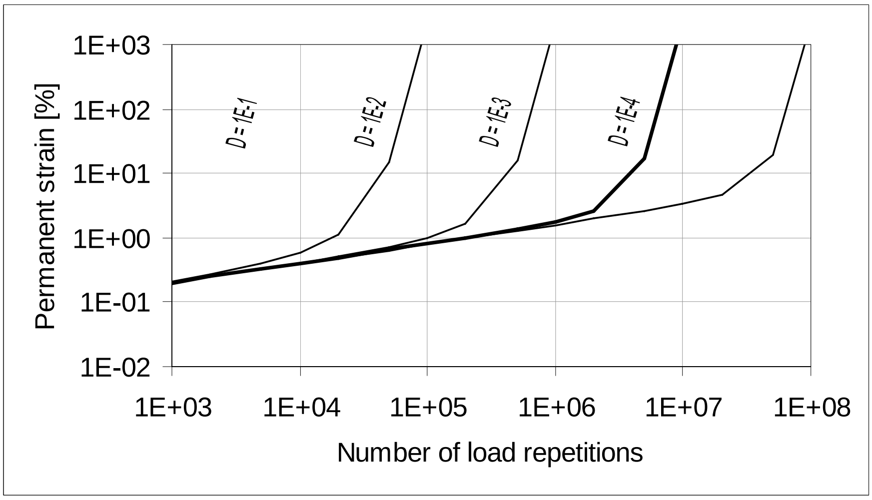


Figure E-4: The effect of changing model parameter D on the PD curve (Ebels, 2008)

In Figure E-1 it can be seen that model parameter A does not influence the shape of the PD curve, but only the vertical positioning thereof. The value of model parameter A is equal to the permanent strain at N = 1000. Model parameter B determines the slope of the linear part (on log-log scale) of the PD curve. It can also be seen from Figure E-2 that a lower B parameter "brings forward" the flow point, which defines the initiation of the tertiary flow phase. The flow point occurs where the slope of the linear part is equal to the tangent of the tertiary flow part.

Model parameter C determines the "abruptness" of the transition from the linear phase to the tertiary flow phase, whereby a lower value for the C parameter results in a more abrupt transition. The asymptotic limit whereby $\varepsilon(N)$ □ ∞ is not influenced by the C parameter. This asymptotic limit is only influenced by model parameter D. A higher D parameter "brings forward" this limit. This limit exists for as long as $C \neq 0$ and even for very small values for C and D tertiary flow will eventually set in, albeit far beyond N values that have any relevance to pavement engineering.

2.3. Stress dependency of model parameters

Huurman (1997) stated that the model parameters *A*, *B*, *C* and *D* are a function of the applied stresses and that this stress dependency can be described by taking into account the ratio of applied major principal stress and the principal stress at failure. Jenkins (2000) and van Niekerk

(2002) found for the deviator stress ratio and not the major principal stress ratio to be a fundamental performance parameter and adjusted stress dependency of the model parameter *X* as follows:

$$X = x_1 \left(\frac{\sigma_d}{\sigma_{d,f}} \right)^{x_2} \qquad \text{Eq. E – 2}$$

In this equation x_1 is called "the multiplier", while x_2 is called "the exponent". To illustrate the effect of change in the model parameter *X* as a results of changing model coefficients a_1, a_2, b_1, …, d_2 two graphs are shown in Figure E-5 and Figure E-6 respectively. In Figure E-5 the exponent (model coefficient x_2 = a_2, b_2, c_2 or d_2) is kept constant at a value of 2, while multiplier (model coefficient x_1 = a_1, b_1, c_1 or d_1) is varied. In Figure E-6 the multiplier is kept constant at a value of 5, while the exponent is varied.

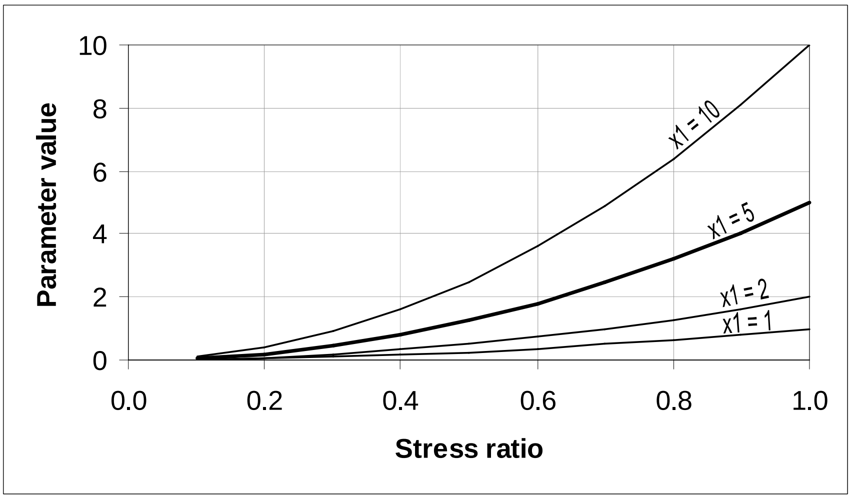


Figure E-5: The effect of changing the multiplier x_1 on the model parameter *X* (Ebels, 2008)

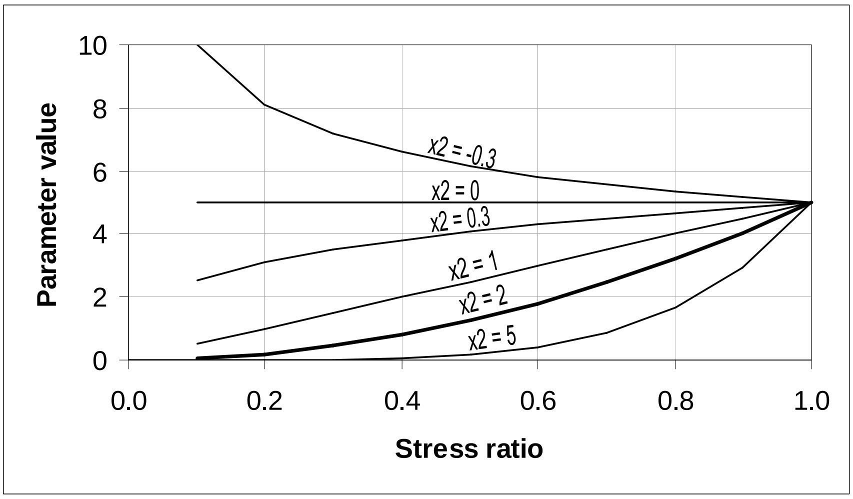


Figure E-6: The effect of changing the exponent x_2 on the model parameter *X* (Ebels, 2008)

In general terms the exponent determines the shape and slope of the stress dependency curve. The effect hereof for increasing stress ratios is either increased ($x_1 > 1$), decreased ($x_1 < 1$) or remains the same ($x_1 = 1$). For a constant multiplier, the parameter value *X* for different exponent values converges at a stress ratio of 1.0 (see Figure E-6). At a stress ratio of 1.0, the parameter value (X = A, B, C or D) is equal to the value of the multiplier. This is illustrated by Figure E-5.

Ebels (2008) extended the method for determining the model parameters and coefficients as discussed above. Ebels' method is a combination of both linear and non-linear regression and converges at solutions for the C and D model parameters.

2.4. Permanent deformation curves and model coefficients

The BSM mixes discussed in this section were tested at the Stellenbosch University by Ebels (2008). Details of the mix composition and labelling are given in Appendix C in the discussion of Task 3 of this project. The model coefficients a_1, a_2, b_1, …, d_2 as discussed above are summarised in Table E-1.

Table E-1: Model coefficients of PD curves according to type of binder (bitumen emulsion or foamed bitumen) and type of aggregate blend (Ebels, 2008)

Mix	Model coefficients							
	a_1	a_2	b_1	b_2	c_1	c_2	d_1	d_2
A+B-75C-0	0.92	1.45	0.66	1.47	$1.9\cdot10^{-7}$	-12.14	$7.9\cdot10^{0}$	8.72
C-75C-0	6.16	2.07	14.54	4.27	$2.1\cdot10^{-3}$	-8.41	$1.3\cdot10^{-3}$	10.72
A+B-75C-1	2.53	2.39	2.31	2.47	$4.9\cdot10^{2}$	18.09	$3.3\cdot10^{1}$	7.81
C-75C-1	0.59	0.90	2.29	3.30	$7.3\cdot10^{-2}$	11.18	$1.5\cdot10^{2}$	12.66
A+B-75M-0	0.83	0.75	1.74	2.05	-	-	-	-
C-75M-0	0.43	1.00	0.60	1.04	$1.0\cdot10^{-1}$	2.61	$2.4\cdot10^{-1}$	7.80

The data of the two bitumen emulsion mixes are combined and one model permanent deformation curve, depending on the type of blend used, describes the permanent deformation behaviour of the two bitumen emulsion mixes (Emulsion A and Emulsion B). The number of model permanent deformation curves is therefore reduced to six from nine mixes, *i.e.* three bitumen emulsion model curve sets (A+B-x-x) and three foamed bitumen model curve sets (C-x-x). These three sets for each binder type consist of one set for the aggregate blend with 75% crushed rock and no active filler (75C-0), one for the aggregate blend with 75% crushed rock and 1% active filler (75C-1) and one set for the aggregate blend with 75% RAP and no active filler (75M-0).

Because no tertiary flow was observed for the A+B-75M-0 mixes, no values for the model parameter C and D could be determined. The stress dependency of the model parameter A, B, C and D as numerically expressed by the model coefficients shown in Table E-1, is graphically shown in Figure E-7 to Figure E-10 respectively.

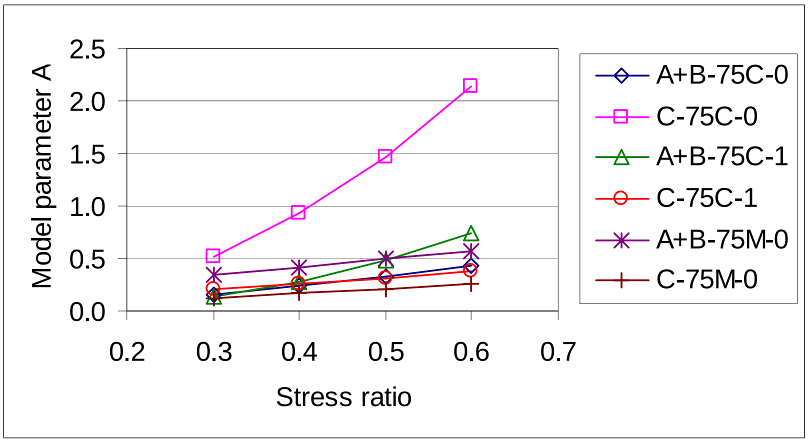


Figure E-7: Stress dependency of model parameter A (Ebels, 2008)

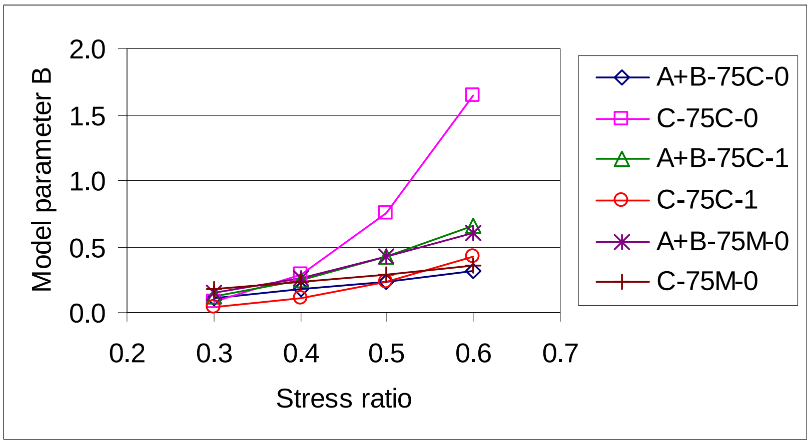


Figure E-8: Stress dependency of model parameter B (Ebels, 2008)

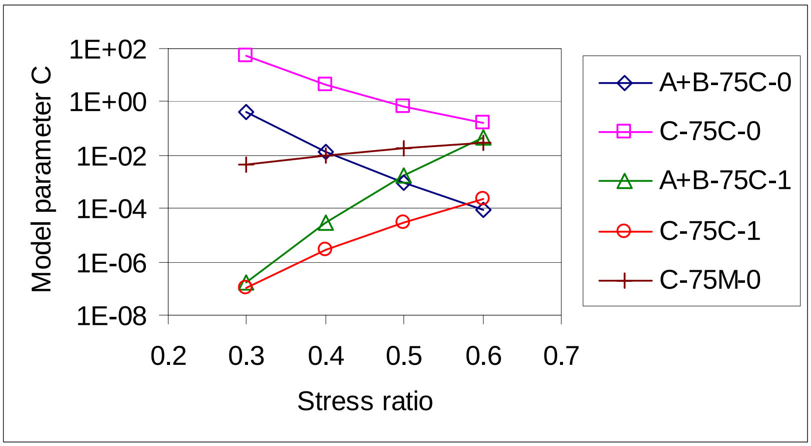


Figure E-9: Stress dependency of model parameter C (Ebels, 2008)

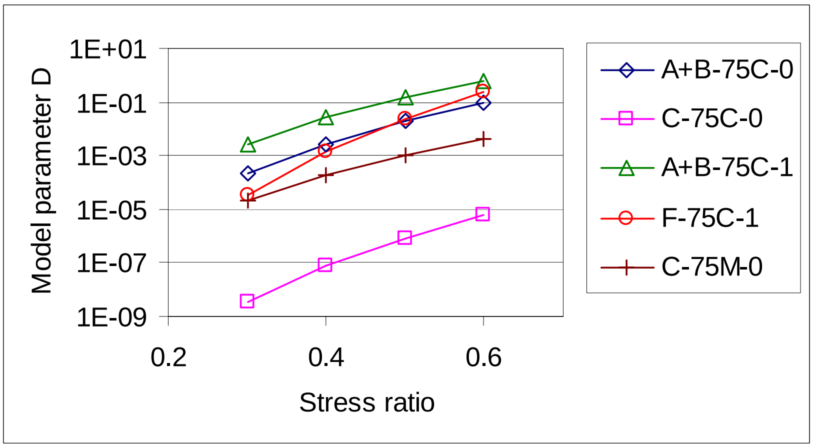


Figure E-10: Stress dependency of model parameter D (Ebels, 2008)

With the model coefficients summarised in Table E-1 model fits such as those shown in Figure E-11 and Figure E-12 are obtained. The model fit shown in Figure E-11 is a typical example of the PD behaviour of a BSM material with active filler. A well defined flow point and tertiary flow phase can clearly be distinguished for all stress ratios tested. The model fit shown in Figure E-12 is a typical example of a BSM material with a high percentage of RAP and stabilised with bitumen emulsion. No tertiary flow can be distinguished.

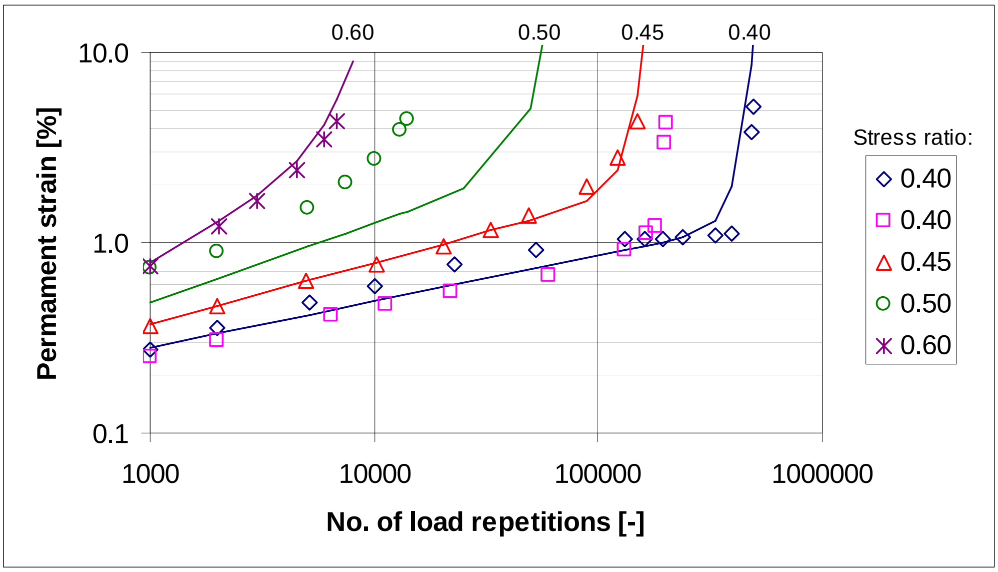


Figure E-11: PD curves A-75C-1; experimental data and model fits (Ebels, 2008)

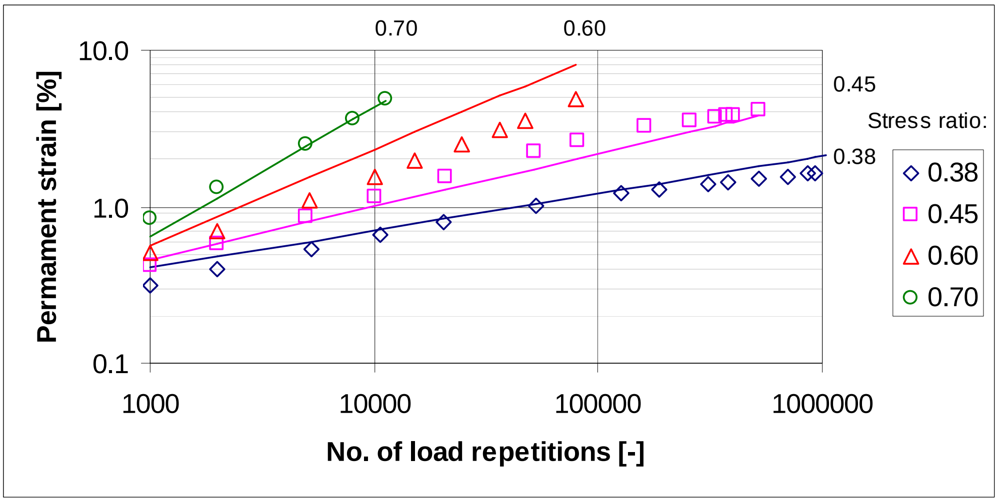


Figure E-12: PD curves B-75M-0; experimental data and model fits (Ebels, 2008)

Ebels (2008) provided model fits of all nine mixes discussed in this section. The figures with model fits can be used as a template or the model coefficients in the General Permanent Deformation Law for comparable BSM mixes in order to estimate the permanent deformation behaviour in the repeated load tri-axial test.

2.5. Critical deviator stress ratios

As stated in the discussion of the phases of permanent deformation, the tertiary flow phase is initiated by the flow point. Whether or not a flow point occurs depends on a number of factors, one of which is the applied deviator stress ratio. A critical deviator stress ratio exists. When a material is repeatedly loaded above this critical deviator stress ratio the permanent deformation behaviour includes a third phase as described above. Repeated loading below this critical stress ratios results in an ongoing stable second phase behaviour. The critical deviator stress ratios as identified for the mixes tested by Ebels are summarised in Table E-2:

Table E-2: Range of critical deviator stress ratio summarised per mix composition and binder type (σ_3 = 50 kPa, 25 ºC and 2 Hz) [Ebels, 2008]

Mix composition	Emulsion A	Emulsion B	Foamed Bitumen C
75C-0	0.30 – 0.40	0.50 – 0.60	0.40 – 0.50
75C-1	< 0.40	< 0.45	0.40 – 0.50
75M-0	0.45 – 0.50	0.45 – 0.60	0.45 – 0.60

The addition of 1% active filler (cement) to the 75C mixes results in similar first and second phases of permanent deformation accumulation, but a much more abrupt third phase. While the mixes without active filler exhibit a gradual acceleration in the accumulation of permanent deformation, the mixes with active filler fail relatively quickly after the second phase. This effect is most pronounced for Bitumen Emulsion A and Foamed Bitumen C.

Ebels (2008) furthermore concluded that the initial plastic strain for the mixes with a high percentage of RAP (75M-0 mixes) is higher than for the mixes with predominantly crushed stone (75C-0 mixes). The rate of accumulation of permanent deformation during the secondary phase is also higher for the 75M-0 mixes. This is however compensated by the fact the 75M-0 mixes can withstand higher levels of plastic strain before tertiary flow initiates. This may indicate that mixes with a high percentage of RAP have initially less resistance to permanent deformation, but are tougher at high plastic strain levels. The former may be caused by the fact that the friction angle of the 75M-0 mixes is much lower than the 75C-0 mixes. The latter may be the result of the higher cohesion and the interaction between the newly added binder and the binder already present in the RAP material.

Based on the above, one could state that BSM's with a high RAP percentage are more ductile, even though in the mixes tested by Ebels the residual binder added to the mixes with a high percentage of RAP was lower than for the mixes with predominantly crushed stoen (2.4% versus 3.6%). Furthermore, it can be seen from Table E-2 that the critical stress ratio for the 75M-0 mixes (all binders) is the highest of the three types of mix composition. This critical stress ratio is fairly constant over the range of binders tested and can be as high as 0.60.

2.6. Applied deviator stress ratio in relation to performance

Ebels and Jenkins (2006) determined, for the mixes discussed above, the influence of the stress ratios on the number of load repetitions to reach a certain strain level. This is summarised in Figure E-13 and Figure E-14 for 1 % and 4 % plastic strain respectively. For a 200 mm thick pavement layer 1 % strain equates to a total deformation of 2 mm at the top of the layer. For 4 % strain this is 8 mm at the top of the layer.

No experimental data for strain levels in excess of 4% strain exists, as beyond this strain level the tri-axial specimen is considered to have failed (excessive bulking and deformation).

The mixes with active filler seem to be more sensitive to the stress ratio. For both bitumen emulsions and the foamed bitumen tested at the Stellenbosch University, the reduction in allowable number of load repetitions with increasing stress ratio is higher for the mixes with active filler than for the mixes without active filler. This is most clearly demonstrated by comparing mix A-75C-0 and A-75C-1 (Figure E-14). The same effect can also be seen in Table E-2, where the critical stress ratio range is generally lowest for the 75C-1 mix for each binder type. The critical stress ratio for cemented mixes appears not to exceed 0.45.

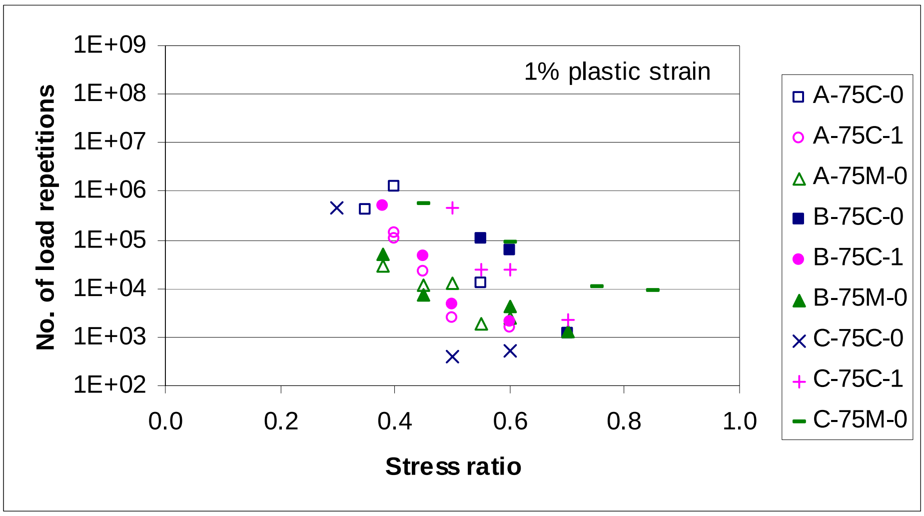


Figure E-13: Influence of deviator stress ratio on permanent deformation to achieve 1% plastic strain (Ebels, 2008)

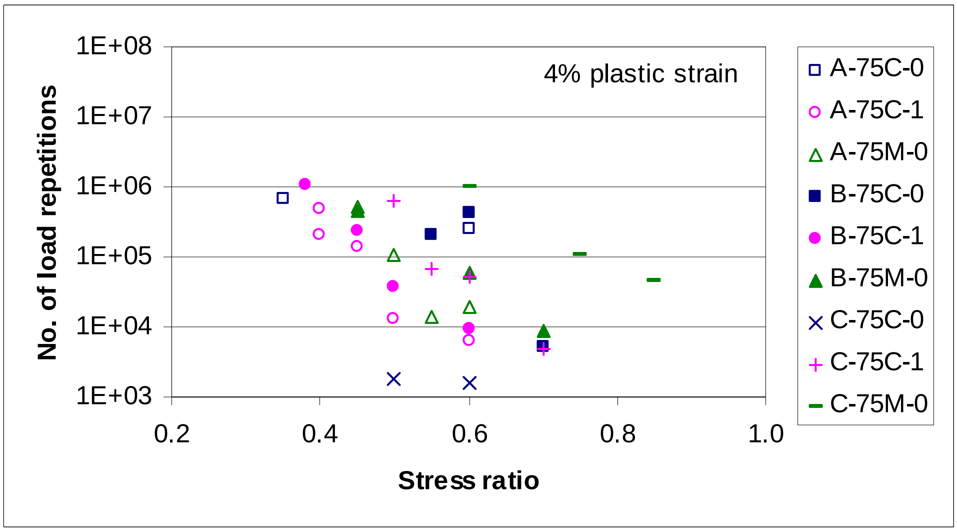


Figure E-14: Influence of deviator stress ratio on permanent deformation to achieve 4% plastic strain (Ebels and Jenkins, 2006)

Jenkins *et al.* (2007) identified a "zone of concern" for unconservatively high estimations of the allowable number of load repetitions to reach a certain plastic strain level, being the result of extrapolating the test results of fairly short duration permanent deformation tri-axial tests. The zone of concern is for stress ratios in excess of the critical stress ratios as shown in Table E-2.

An example of such unconservative estimations is the data labelled P243 shown in Figure E-15 (after Long and Theyse, 2005). The results of some of the mixes tested by Ebels (2008), which are actual results of long duration permanent deformation tests, are also shown in Figure E-15. The test results obtained by Ebels confirm the "zone of concern" identified by Jenkins *et al.* (2007). Hence, it can be concluded that it is unlikely to obtain high numbers of load repetitions to achieve 4 % plastic strain at stress ratios in excess of the critical stress ratio reported by Ebels (2008).

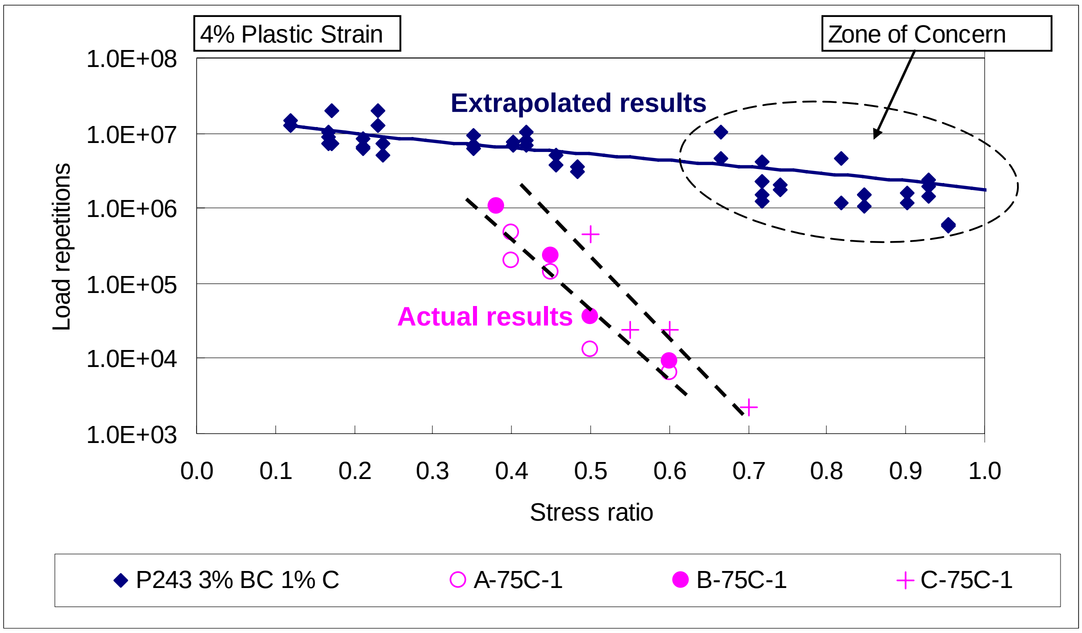


Figure E-15: Influence of deviator stress ratio on number of load repetitions to achieve 4 % plastic strain (Ebels, 2008)

Figure E-15 clearly illustrates that by extrapolating the N-ε curve of a permanent deformation tri-axial test that true permanent deformation behaviour of BSM, especially at stress ratios in excess of the critical stress ratio, can be grossly overestimated.

2.7. Indicators for permanent deformation performance

Ebels and Jenkins (2007b) identified the initial permanent strain and the initial permanent strain rate as early indicators of the performance of BSM mixes in the permanent deformation tri-axial test. These parameters are defined as the permanent strain and strain rate respectively after 1,000 load repetitions as shown in Figure E-16.

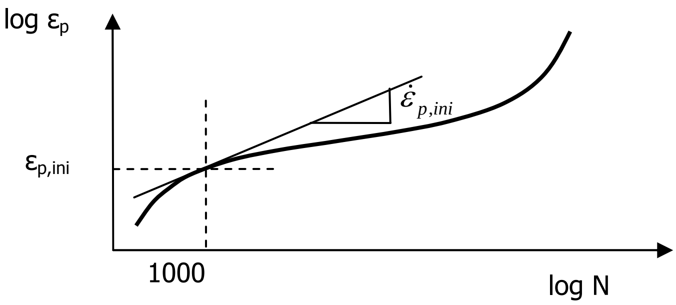


Figure E-16: Definition of initial strain and initial strain rate

Generally good correlations exist between these two parameters and the Model Parameter A and B respectively. This renders these two parameters, that can be obtained early on during the permanent deformation tests (after only 1,000 load repetitions), very useful to estimate the Model Parameters A and B. Ebels (2008) developed relationships to this extent as shown in Figure E-17.

With an estimate for Model Parameters A and B in hand, the permanent deformation behaviour of the emulsion mixes with a high percentage of RAP (E-75M-0) can be estimated as no tertiary flow was observed for these mixes. For the other mixes it is only the Model Parameter D that is further required to estimate the permanent deformation behaviour. For the stress ratios below the critical stress ratio even this is not required because the second term in the general permanent deformation law diminishes for lower stress ratios and tertiary flow does not occur.

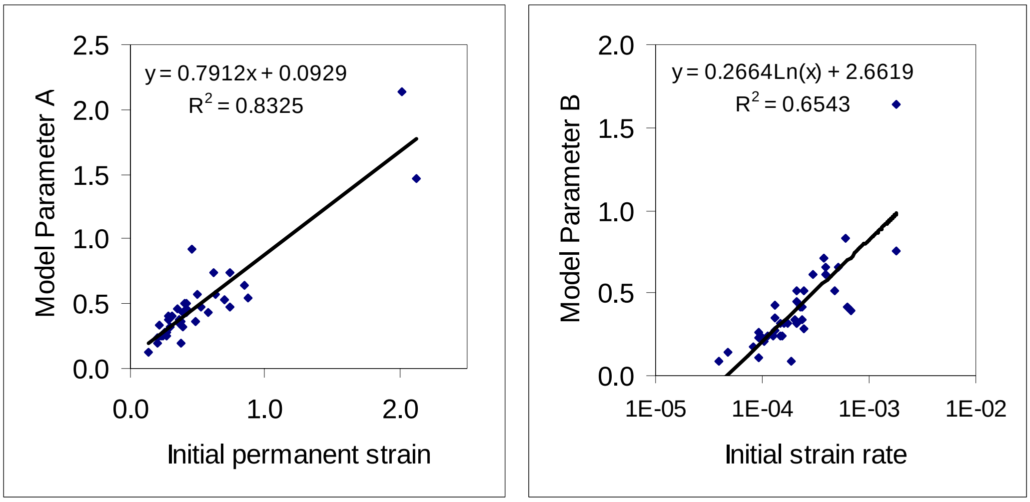


Figure E-17: Correlation between the initial permanent strain and initial strain rate (all mixes tested) derived from the permanent deformation test and Model Parameters A and B respectively (Ebels, 2008)

Ebels (2008) found that the general permanent deformation behaviour of BSM's can be described by six scenarios and that the most likely scenario can be evaluated by the three most important model parameters in conjunction, *i.e.* model parameters A, B and D. The six scenarios of material behaviour are summarised in Figure E-19. The same figure provides a flow chart of the three most important model parameters that, depending on their value, lead to the most likely scenario. When only the A-parameter is high, failure is possible, but difficult to predict with confidence. In combination with a high D-parameter, early failure with tertiary flow is likely to occur. High values of parameter B, regardless of the other parameters, are likely to results in failure. When only the D-parameter is high, the behaviour will initially be stable, possibly with tertiary flow later on.

The stress dependency of Model Parameter D is per mix shown in Figure E-18. With knowledge of the type of BSM mix and the applied deviator stress ratio, an estimate of the value of Model Parameter D can be made.

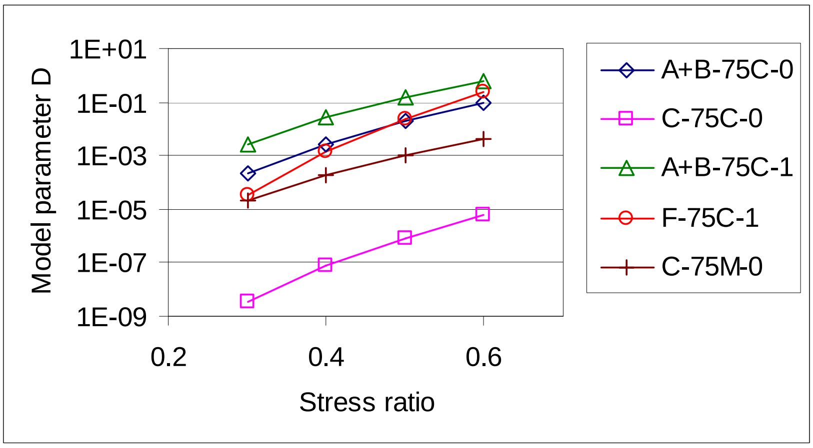
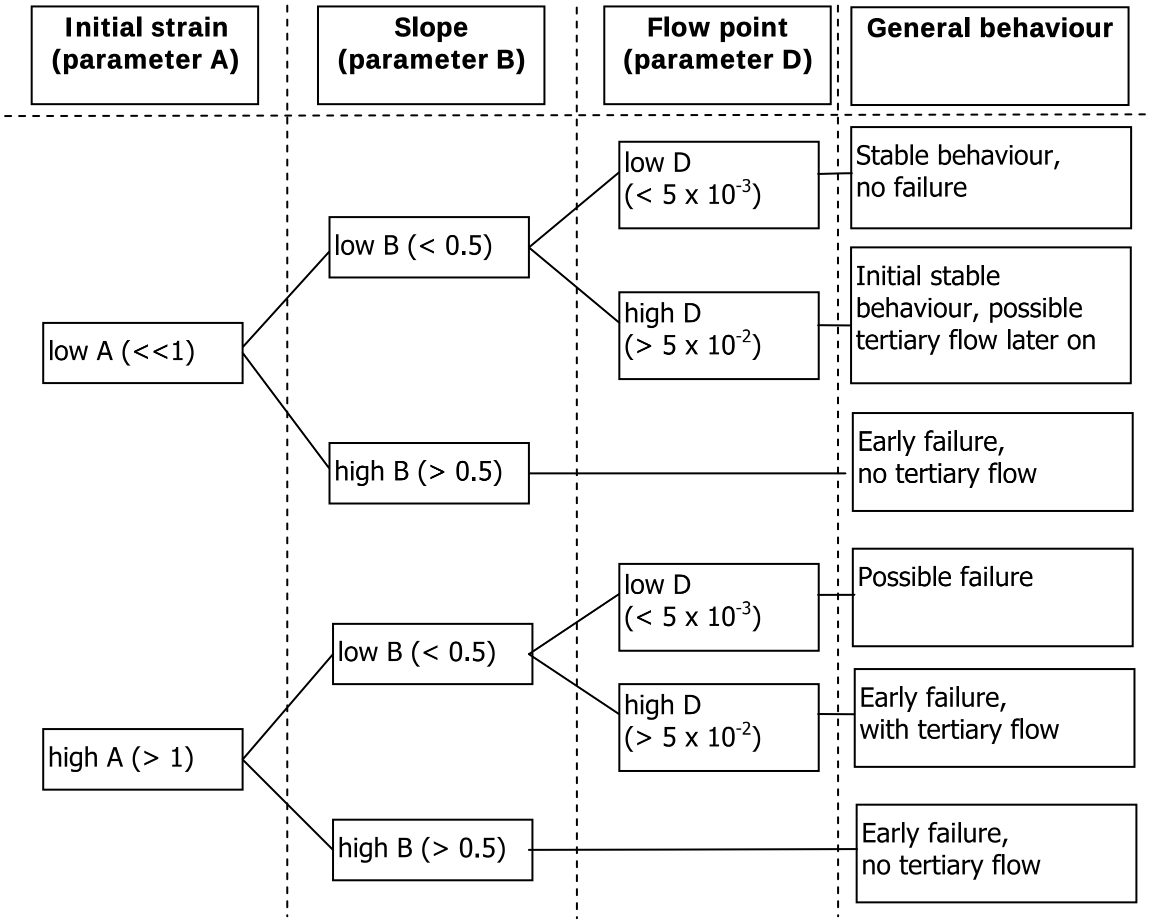


Figure E-18: Stress dependency of model parameter D

The extent to which the model parameters are dependent on each other is difficult to determine, based on the limited number of variables that have been tested in this study. It is recommended that this dependency and especially the relation between compositional factors and the model parameters be studied further.



Note: The coefficient values provided are approximate values and are indicative only

Figure E-19: Material behaviour scenario flow chart (Ebels, 2008)

2.8. Limitations of current data set

The available permanent deformation tri-axial test data analysed in this task is based on testing with certain fixed test conditions. It had been identified during the work carried out under Task 1 of this project, that there are differences in the test conditions adopted at the CSIR and at the Stellenbosch University. The most important test conditions of the permanent deformation tri-axial test were identified as:

- Loading frequency;
- Loading wave shape (including presence and length of rest period);
- Test temperature; and
- Confinement pressure.

A testing schedule to study to effect of each of the above parameters was developed, which forms the basis of the testing to be carried out under Task 6, Advanced Classification System for

Cold Mixes Based on Repeated Load Permanent Deformation Tri-axial Test Part II. This schedule is shown in Table E-3. The same type of mix would be subjected to all the test variables. Tests would also be performed at the standard test condition to serve as a reference.

Table E-3: Test schedule permanent deformation tri-axial testing Task 6

Test condition	**Standard (SU) condition**	**Variations to be tested**
Loading frequency	2 Hz	0.1 Hz, 0.5 Hz, 1 Hz and 5 Hz
Loading wave shape	continuous haversine	square wave haversine + short rest period haversine + long rest period
Temperature	25 ºC	10ºC, 40 ºC
Confinement pressure	50 kPa	100 kPa

3. CONCLUSIONS AND RECOMMENDATIONS

- The General Permanent Deformation Law, as originally developed by Francken (1977) and as later adjusted by Huurman (1997), Jenkins (2000) and van Niekerk (2002) for unbound and bound granular materials, has been used here as a basis for the analysis of permanent deformation behaviour of BSM in the repeated load tri-axial test.

- The permanent deformation behaviour for selected BSM mixes at the Stellenbosch University has been analysed. This includes determining the model parameter of the Permanent Deformation Law, as well as the stress dependency thereof. Templates showing the permanent deformation curves as a function of the stress ratio have also been developed.

- The permanent deformation behaviour of BSM's consists of three phases , i.e. a initial bedding-in phase, a stable secondary phase with steady accumulation of permanent strain and a tertiary flow phase with accelerating strain accumulation. The material may be considered to have failed if tertiary flow occurs. The tertiary flow phase is initiated by the flow point. This is defined as the number of load repetitions at which the rate of strain accumulation is minimal and after which the strain accumulation starts to accelerate again.

- The occurrence of a flow point and tertiary flow depends on the level of applied stress. When the applied deviator stress ratio is low enough, tertiary flow does not occur and the permanent deformation of the mix remains stable. When the applied deviator stress ratio exceeds a certain critical ratio, tertiary flow does start to occur. Critical stress ratios for a number of selected BSM mixes have been determined. These vary, depending on the type of mix, from 0.30 to 0.60. When BSM's are loaded in excess of a deviator stress ratio of 0.60, tertiary flow sets in almost immediately, i.e. within the first 10,000 load repetitions.

- Certain test conditions of the permanent deformation tri-axial test have been identified as required further research. These are the loading frequency, loading wave shape (including rest period), test temperature and confinement pressure. A testing schedule has been developed to study the effect of changes in these conditions. This forms the basis of further testing to be carried out under Task 6

- It has been identified that the permanent deformation behaviour of BSM's are to a large extent determined by the Model Parameters *A*, *B* and *D* of the General Permanent Deformation Law. A good correlation appears to exist between the initial strain and initial strain rate as defined by Ebels and Jenkins (2007) and the Model Parameters A and B respectively. The values for the initial strain and initial strain rate can be obtained early on during the permanent deformation test (after 1,000 load repetitions). With some knowledge of Model Parameter D, the permanent deformation behaviour of the BSM can now be predicted. Model Parameter D is, to a large extent, related to the critical stress ratio.

- A flow chart with most likely scenarios of permanent deformation behaviour depending on Model Parameters A, B and D has been developed. This could serve as the basis for classification of BSM material categories.

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