CHAPTER 9 CONCLUSIONS AND RECOMMENDATIONS

The conclusions and recommendations relevant to the particular chapter have been listed at the end of each chapter. This chapter contains the overall recommendations and conclusions from this study.

From the literature study, it is clear that mix design practices for emulsion treated materials are well established and researched, but do not provide much 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. Several mix 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 life cycle behaviour and failure criteria of pavement layers treated with bitumen emulsion and to develop transfer functions for the relative mode of failure to load repetitions. From the laboratory and Heavy Vehicle Simulator (HVS) study, it was possible to define the life cycle behaviour and transfer functions, as well as a structural design procedure were developed for these types of materials.

9.1 CONCLUSIONS

- The cement and net bitumen content have an influence on the important engineering properties. If the cement content 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 2 700 MPa depending on these parameters. This study includes only materials with net bitumen content of between 0.6 and 3.0 % and cement content between 1 and 2 %.

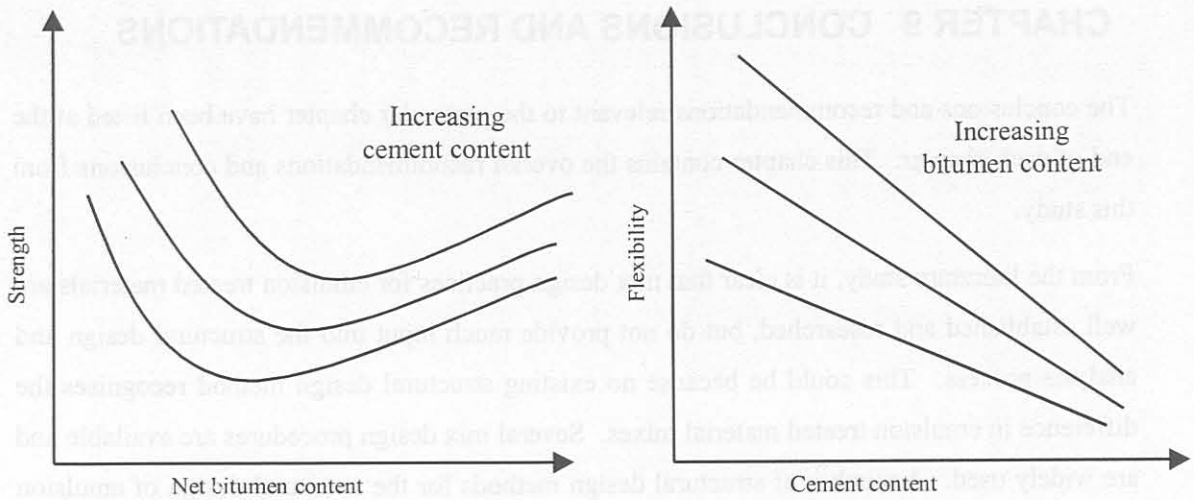

Figure 9.1 Influence of cement and net bitumen content on main engineering properties

- The Initial Consumption of Lime (ICL) is an important indicator of the behaviour of emulsion treated material. Below the ICL the cement acts mainly as an catalyst to assist in the breaking of the emulsion and does not contribute much to the strength of the material, as the cement is absorbed in the clay. Above the ICL the cement contributes significantly to the strength and limits the flexibility provided by the bitumen.
- The behaviour of an emulsion treated material is a two-phase behaviour. The first phase is similar to that of lightly cemented material, in the sense that it has an effective fatigue life. In the second phase the material will behave similarly to a granular material with a reduced resistance to permanent deformation.
- The strain at break (ε_b) can be obtained from the flexural beam test and depends largely on the cement and bitumen content of the mix.
- The shear stress parameters, internal friction angle (ϕ) and cohesion (c), can be obtained from static triaxial testing in the laboratory. The internal friction angle is influenced not much by a change in the cement or net bitumen content. The cohesion could vary between 200 and 300 kPa depending on the quality of the parent material, the cement content and the net bitumen content.
- Under HVS testing the backcalculated stiffness converges to a value of 500 MPa after a number of load repetitions. This was assumed to be the end of the fatigue life phase and the beginning of the "equivalent granular" phase. The terminal stiffness value also depends on the quality of the parent material, the cement content and the bitumen content. It is expected that the value could range between 400 and 600 MPa depending on the factors mentioned.
- The permanent deformation performance of the material considered was good under HVS testing. Less than 5 mm of permanent deformation was measured on all the test sections

after the termination of the tests. The introduction of water into the pavement decreased the permanent deformation resistance of the layer.

- Using the developed transfer functions, and the principles of the South African Mechanistic Pavement Design Method, it would be possible to model the behaviour of emulsion treated materials for rehabilitation analysis and design.
- A design catalogue was developed in accordance with the principles of the TRH4 and South African Mechanistic Pavement Design Method. The catalogue provides different pavement structures for different traffic classes and road categories.
- Material parameters, for the use in the mechanistic analysis process, have been derived in this study and should be used as a guideline only.

9.2 RECOMMENDATIONS

- The design method proposed in this study should be introduced as an *interim* guideline to the industry until such time as more knowledge on bitumen emulsion treated stabilised materials are obtained.
- Where possible, material properties should be measured in the laboratory and then entered into the structural design process. The material guidelines presented in Table 8.5 should only be used as a *guideline*.
- A database should be set up from projects, where emulsion treatment was used, to assist in the refining of material properties and to broaden the knowledge base to other material types.
- Mix design procedures should be refined to provide input into the structural design procedure.
- Laboratory studies on different cement and bitumen content should be extended to other types of materials.
- Field and HVS studies, on other types of materials and different cement and net bitumen content, are recommended to refine the proposed transfer functions. This may be expensive and should be a long term research objective.
- Finite element studies on the permanent deformation behaviour of emulsion treated materials should be investigated together with the use of elasto-plastic or other non-linear models. This will provide a better understanding and description of the behaviour of pavement structures, which involve emulsion treated materials.