CHAPTER 8

CONCLUSIONS AND RECOMMENDATIONS

CONTENTS PAGE

8.1 CONCLUSIONS AND RECOMMENDATIONS

The conclusions and recommendations relevant to a particular chapter have been listed and discussed at the end of each chapter. This chapter contains only the overall conclusions and recommendations for future research, resulting from this study.

8.1.1 Conclusions

(a) Since the implementation of the Heavy Vehicle Simulator (HVS) test programmes in South Africa during the late 1970s, the understanding of basic pavement behaviour has been and is advancing very rapidly. Amongst others, the definition of the actual in situ pavement system has been identified as one of the most important factors influencing actual pavement behaviour. The difference in quality between cementitious materials produced in the field during the construction process, and those prepared in the laboratory is significant, and a method was urgently needed to identify and quantify these differences. An in situ pavement classification system, based on the results of the Dynamic Cone Penetrometer (DCP) has been developed, and assists largely in the proper definition of the in situ pavement system, ie actual layer thickness and quality.

(b) The dominant failure mechanism in deep pavements with lightly cementitious layers is compression (crushing) failure in the upper 50 mm to 75 mm of the base. The rate of deformation is largely controlled by the initial material state, trafficking wheel load, tyre contact pressure, effective moisture content especially in the top of the base and the degree of balance of the pavement. During wet conditions loss of the surfacing and excessive potholing occurs in the base, while the lower layers may be still in a relatively sound condition.

(c) The dominant failure mechanism in shallow pavements with cementitious layers is fatigue failure of the base, with subsequent deformation ("punch in") into the relatively weaker lower layers. The rate of deformation is largely controlled by the trafficking wheel load, the state and moisture content of the lower layers and degree of balance of the pavement. On the shallow pavements, wheel load is initially more critical than tyre contact pressure, but later during reduced rate in deformation, the effect of tyre contact pressure increases and also produces compression failure in the top of the base, similar to that found for the deep pavements.

(d) The relative damage coefficient, based on the rate of deformation of these pavements with cementitious layers, is relatively low, and varies between 1,2 and 1,5 for deep, and 1,6 and 1,8 for shallow, and up to 4,5 for very shallow pavements. For equivalent fatigue failure (based on equivalent induced maximum tensile strain at the bottom of the base) these values increased to 2,8 for the deep, and 3,9 for the shallow pavements evaluated in this study.

(e) Compression (crushing) failure of lightly cementitious layers occurs with compressive axial strains in excess of approximately one per cent. Compression failure is noted by a marked reduction in the effective cohesion (cementation), initially introduced in the material to improve its strength (bearing capacity).

(f) The rate of compression failure is largely controlled by the initial material strength in the upper 50 mm to 75 mm of the base layer and the tyre contact pressure. The implications of this type of failure should be considered during the design phase, for which tentative guidelines are also given.

(g) The DCP aided in the description of the behaviour of the pavements in this study, and enabled better understanding of the actual pavement behaviour and failure mechanisms. The concept of pavement strength - balance paths assist largely in describing the behaviour more quantitatively than was perhaps done in the past. According to this concept both pavements evaluated became "deeper" as a direct result of trafficking.

(h) An alternative DCP model for the prediction of structural capacity for pavements with lightly cementitious layers was developed, as it was found that a current model, which was developed in the early 1980s mainly for light pavements with unbound gravel bases, largely overestimates the capacity for the pavements evaluated in this study. The alternative model predicts the linear rate of deformation based on two DCP parameters calculated from the DCP data.

(i) As with the permanent behavioural changes in the pavement, such as permanent deformation, crushing and cracking, the resilient response and behaviour are very useful in the furthering the understanding of mechanistic pavement behaviour. Both surface and depth deflections were used as input to the successful modelling of both the deep and shallow pavements, based on the linear elastic theory.

(j) The concept of effective fatigue life of lightly cementitious layers is introduced, as it was found that the current prediction model totally under predicts the actual (effective) fatigue life of these layers.

(k) The change in effective elastic moduli of the cementitious base layers of both pavements was quantified and it was found that those of the deep pavement decreased hyperbolically to a range of 200 MPa to 300 MPa, mainly as a result of crushing failure, and that of the shallow pavement to approximately 500 MPa, mainly as a result of fatigue failure.

(l) The effective elastic moduli of all the lower layers in both pavements also reduced as a result of traffic loading, but at variable rates and magnitudes.

(m) Both maximum tensile strain and vertical compressive strain in both pavements increased as a result of trafficking, and are associated with changes in permanent deformation of up to 20 mm.

(n) It was found that the vertical compressive strain contribute largely in explaining the actual failure mechanisms experienced for both pavements evaluated.

(o) The current limiting compressive strain criteria for subgrades were verified for the pavements evaluated and appear to be accurate. They also predict the associated permanent deformation accurately at virtually any depth within the pavement.

8.2 Recommendations for future research

(a) The DCP classification system proposed in Chapter 3 should be applied to pavement types other than those evaluated in this study, to verify its wider application.

(b) The following concepts identified during this study should also be verified for a wider range of pavement types, including, for example, pavements with bitumin emulsion treated bases :

- Traffic associated strength - balance paths
- Compression failure in the upper part of the base
- Effective fatigue life
- Vertical strain/permanent deformation quasi - elastic analysis

(c) Current finite element theory and available software should be investigated and models calibrated in order to predict pavement behaviour using <u>in situ determined</u> stress dependent characteristics such as the effective elastic moduli, Poisson's ratio, etc., of these lighlty cementitious materials. Research done by Duncan et al. (1968), Wilson (1965)) and Maree (1982) should also be consulted in this respect.

(d) It is strongly recommended to continue with the HVS testing on pavements with lightly cementitious layers in order to evaluate already proposed rehabilitation strategies, based on the findings of this study. Construction work on three experimental sections on the relatively shallow pavement on road 2212, near Bultfontein in the Transvaal, is currently underway, and includes pavement sections where the in situ cementitious base layer was pre - cracked, using large vibratory rollers. Three basic rehabilitation options have been selected and include a 150 mm G1/2 base, 35 mm asphaltic surfacing and a conventional double seal on the cracked pavement.

In Appendix D, Photo Plates D.25 to D.28 illustrate aspects of the preparation of these experimental sections near Bultfontein (Road 2212).

(e) Evaluation of the erodibility of lightly stabilised materials should be extended to include stabilisers such as fly-ash, bitumin emulsions, granulated slag, reverseals, etc. The effects on erodibility of the following also needs attention:

- Carbonation (both detrimental and advantageous) of lime and cement treated pavement materials
- accelerated curing on long term durability

(f) Calibration of the Erosion test with other durability tests such as the mechanical wet-dry brushing test, etc.

(g) The current proposed tentative erodibility criteria (De Beer, 1989) should be incorporated in the current specifications for cementitious materials, and further research should be guided to obtain a broader experience base with the Erosion Test in order to improve on the proposed criteria, if necessary.

8.2 REFERENCES

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