A STUDY INTO THE BEHAVIOUR AND USE OF ASPHALT CONCRETE SURFACINGS OVER UNBOUND BASES IN KENYA

by

Graham A. Hall

A thesis submitted in fulfilment for the Degree of Doctor of Philosophy in the University of Nairobi

1979

SUMMARY

This study is primarily concerned with road pavements built in Kenya comprising layers of unbound crushed rock and natural gravels surfaced with asphalt concrete. Observations made on the mode of failure of these roads indicate that the primary distress mechanism is the weakening of the surface layer by traffic fatigue. The physical manifestation of fatigue is cracking of the surfacing layer. These cracks enable water to enter directly into the lower pavement layers to weaken them and thereby accelerate deformation.

Design specifications used in other countries with similar climatic conditions are examined; if these were adopted in Kenya they would mean greater thicknesses of surfacing than is present customary, and consequently a greater first cost of construction. It can be argued that thicker surfacings reduce maintenance costs and increase the period before major re-habilitation becomes necessary; this contention requires examination under conditions prevailing in Kenya.

A deterministic analytical approach is utilized to show that inadequate warning of fatigue-type failure in the surfacing is given by the existing empirically-based design method; this emphasises the need for a design procedure based, at least partly, on the engineering properties of the highway materials. The problem of determining the mechanical state of such a pavement system is firstly divided into two elements, (i) determination of the response of the surfacing layer, and (ii) measurement of 'support' given by the unbound pavement layers, while secondly, the performance of examples of the total system in-service are critically examined.

The visco-elastic nature of the asphalt concrete is reviewed; in-service measurements show that the recoverable deflections have both time-dependent and stress-dependent components. The time-dependent deflection becomes significant above 45°C. In-service properties of asphalt concrete mixes are reported: for example, it is shown that the Penetration values of stock 80/100 pen. bitumens drop by 43% after mixing and a further 30% between

eighteen and thirty-three months after laying. The response of asphalt concrete is primarily a function of loading time and temperature. Moduli values calculated from in-service mix details show that temperature exerts the major influence with typical field stiffness values ranging from 60,500kg/cm^2 at 18.6^{o}C to 3,000kg/cm^2 at 46.4^{o}C. Temperature data is analysed and equations prepared that enable asphalt slab temperatures at depths up to 150mm to be predicted from knowledge of the air temperature. In-service temperature measurements are presented to confirm the accuracy of these prediction procedures for the Nairobi area; in these cases temperature differences between the bottom and top of the slab are shown to vary from +8.4^{o}C to -21.6^{o}C and +8.7^{o}C to -27.3^{o}C in 100mm and 150mm thick slabs respectively.

Essential to a rational design method is some form of rapid measurement of the response of the pavement under the stress conditions likely to be encountered in-service. The insitu test method described in this study assesses the structural condition of the pavement in terms of properties of the deflection of its surface under dual-tyre assemblies using the Deflection Beam and either standard BRRL or LCPC trucks. These properties are defined as the maximum deflection, d, and the longitudinal radius of curvature of the deflection bowl, R. Previous workers used linear elastic theory to develop relationships in a two-layer system between Rd and the modular ratio of the two layers, and the determination of the bottom layer modulus (ie subgrade) from a knowledge of deflection and modular ratio. A field method for determining R and d is described together with investigations made into determining its accuracy and repeatability: Statistical evaluation of results collected from 100mm long Test Sections of pavement is used to introduce the concept of characteristic values of R and d. Further analytical methods are presented to show the range of applicability in real pavement situations of the idealized assumptions made in the linear-elastic approach. Reference stress-states established using the two differently weighted test trucks are used to provide information on the practical significance of non-linear effects in unbound pavement layers.

A number of factors affecting the response of unbound materials are examined in the study. Examples of a high-density (SG 2.80 - 2.85) well-graded soil known as 'magadi', and a low-density (SG 2.12 - 2.32) high-fines content soil designated 'MS 10' are examined. Field deflection results show that CBR values give no indication of the possible in-service resilient behaviour of subgrade soils; the current 'cover' design approach is therefore inadequate for these classes of pavement. Moisture content results systematically collected from a subgrade beneath an asphalt surfaced road confirm an in-service moisture content slightly drier than BSS optimum moisture content. The highly resilient MS 10 subgrades show increases in surface deflection of 70% when the moisture content is raised 10% up to BSS OMC. The analyses of R and d values on the magadi subgrades provide evidence of a marked tendency towards linear-elastic behaviour at in-service moisture contents, while non-linear behaviour is recorded from the MS 10 type. These MS 10 soils have been stabilized with cement: the BRRL-LCPC stress-strain pairs (together with the analyses of the respective R and d values) then provide evidence of linear behaviour at both stress levels.

Evidence is provided to show that the specified gradation of crusher-run roadbase materials provides adequate stability, while the specified field compaction standards can be readily achieved. Additional field compaction provides no significant change in either reduced air voids or increased pavement rigidity values. All unbound roadbase materials tested showed distinct non-linear response when first constructed, this effect being more marked as the thickness is increased. However, service histories of pavements under traffic show that while the MS 10 subgrade pavement remains non-linear in behaviour, the other pavements move towards a linear response after two or three months in-service.

Systematic measurements of rigidity values on 'type' Test Sections of the Trans-Africa Highway have led to the development of deflection histories relating the d and Rdo values of the pavements to the cracking of the asphalt layer in terms of cumulative standard axles. This functional relationship is used to develop a method for evaluating design options and alternative pavement strategies. Examples of the use of this model are presented.

The study concludes that serious consideration should be given to the development of flexible bitumen-bound mixes as alternatives to the current 'rigid-slab' mix approach for surfacing unbound bases in Kenya.