THE CONTROL OF CRACKING IN RIGID PAVEMENTS

L W Teller

United States Bureau of Public Roads

Everyone is familiar with the fact that rigid pavements crack and since the fault is a common one and not accompanied by loss of life or other disaster there is a tendency to accept this condition as a necessary evil These cracks, however, whether short surface fissures, complete transverse or extended longitudinal fractures are structural defects and should be so regarded

The ideal toward which we should strive in rigid pavement design is an uncracked pavement and this can be accomplished by building it in a series of articulated units each sufficiently strong to resist the external forces which tend to crack the slab In order to design such units the engineer must have a clear understanding of these forces and the manner in which they act as well as a knowledge of those physical properties which determine the behavior of the material employed in the pavement

The principal causes of cracking in rigid pavements are believed to be.

a Temperature change
b. Moisture change
c Changes in the subgrade
d Load effects
e Other factors

In the following discussion the effects of temperature and moisture changes will be considered together since their effects on the pavement are similar Loads are a cause of cracking but this is a problem for the design of the cross-section and will be treated as such in another part of the committee report

Research has demonstrated that either a change in temperature or a change in moisture content of concrete will cause a corresponding change in its volume A rise in temperature or an increase in moisture causes concrete to expand while a fall in temperature or a decrease in the moisture content causes a corresponding shrinkage Both of these changes may occur simultaneously and their effects will be additive. This information is directly applicable to concrete pavements As soon as the concrete has been placed it begins to lose moisture and as it dries out it contracts The surface loses moisture more rapidly than the interior of the mass and thus a differential shrinkage occurs subjecting the outer skin to tensile stresses which may easily exceed the small tensile strength which has been attained Such a condition tends to cause numerous small surface fissures to form This rapid moisture loss from the surface of the freshly laid concrete can be prevented by proper methods of curing This type of cracking is or may become a structural defect and deserves attention but it is not so important from the standpoint of design as the cracks which extend the full depth of the pavement slab As the pavement as a whole loses moisture or is subject to a drop in temperature (or both) it tends to contract from the free ends of the slab toward the center If the slab rested on a frictionless surface this shortening would take place without the development of stress Actually, however, this movement is resisted by a very considerable force of friction whose magnitude depends on the type, smoothness and moisture condition of the subgrade and on the extent of the movement These forces accumulate until they exceed the tensile strength of the cross-section and rupture occurs

It is pertinent to inquire at this point what information is available which will enable the engineer to design units which will be strong enough to resist the external forces thus developed and will remain structurally intact when these changes occur

EFFECT OF MOISTURE

Moisture affects concrete as it does wood, i e , increase in moisture causes expansion and decrease in moisture causes contraction This volume change is affected by a number of factors such as the particular cement used, the cement factor, the aggregates used and the conditions of exposure Concrete which is kept continuously saturated appears to remain in a slightly expanded condition, this expansion being on the average about 0 01 per cent for paving mixtures. If this concrete is allowed to dry out it contracts approximately 0 05 to 0 06 per cent. Saturation subsequent to drying out causes expansion but under these conditions the concrete never quite attains its original length The residual shrinkage varies somewhat but seems to be about 0 02 per cent

Another effect of moisture which should be mentioned is that of warping For instance, if the lower surface of a concrete pavement is in contact with a saturated subgrade while the upper surface is exposed to drying winds this upper surface shrinks causing the edges of the slab to curl upward This phenomenon has not been fully investigated but such data as exist indicate that such a condition is roughly equivalent to about a 3°F temperature differential between the upper and lower surfaces

EFFECT OF TEMPERATURE

Mortars and concretes expand with a rise in temperature and contract with a fall The coefficient of linear expansion appears to vary with the richness of the mix, the moisture content, temperature range and perhaps other factors

The richer concretes and mortars seem to have considerably higher coefficients than "lean" mixes Moisture apparently lowers the coefficient Higher temperature ranges apparently produce higher coefficients

While wide differences in these coefficients can occur under extreme conditions, for the usual conditions to which pavement concrete is subjected the thermal coefficient of expansion may be expected to have an approximate value of from 0 0000055 to 0.0000060 per degree Fahrenheit.

A temperature differential between the upper and lower surfaces of a slab will cause a warping of the surface This may be sufficient to actually lift the edges or corners from the subgrade

TENSILE STRENGTH OF CONCRETE

There has been comparatively little research on the resistance of concrete to pure tension. Such data as are available indicate this property to be influenced by the same factors which affect the compressive strength, and further, that the effect of the type of aggregate is more marked

It is indicated by existing data that the tensile strength ranges from about 8 per cent to about 14 per cent of the compressive strength It is believed that for pavement concrete a fair assumption for tensile strength would be 10 to 12 per cent of the compressive strength.

COEFFICIENT OF FRICTION

Tests have shown that the coefficient of friction developed between the pavement and the subgrade varies with the smoothness, type of subgrade material and its moisture condition Its value ranges from less than 0 5 to 2 5 or more Also because of the nature of the subgrade material the coefficient tends to become larger under greater movement. Subgrades of the more usual types damp but firm may readily develop coefficients of 1 5 or 2.0.

CONTRACTION AND EXPANSION JOINTS

A. T. Goldbeck

Director, Bureau of Engineering, National Crushed Stone Association

Cracks in concrete pavements are objectionable and they should be avoided to an extent commensurate with economy in construction and maintenance.

TRANSVERSE JOINTS

It has been shown in the discussion on Control of Cracking that concrete varies in length with changing moisture and temperature conditions