Abridgment

Thermal Susceptibility of Base Course Material: Its Cause and Its Effect on Pavement Cracking

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Previous data have shown that a base course material commonly used in west Texas will undergo volumetric contraction on freezing, and that a portion of this deformation may remain after the material has thawed (1). This contraction is similar to that which occurs in shrinkage drying of stabilized material except that the freeze deformation is cyclic. This continual volume change with freeze-thaw cycling is termed thermal susceptibility. The two components of thermal susceptibility—the freeze coefficient, which represents the contraction on freezing, and the residual coefficient, which represents the permanent deformation—were shown to be related to the suction in the material (Figure 1). The freeze coefficients for the seven base course materials tested averaged an order of magnitude larger than the thermal coefficients for asphalt concrete. This is related to the problem of cracking that originates in the base course due to the buildup of excessive tensile stresses (2).

This paper discusses the material property relations that influence the thermal susceptibility and the physical effects of the thermal susceptibility on the pavement, and makes an initial examination of the effects of stabilization on thermal susceptibility.

MATERIAL PROPERTY RELATIONSHIPS

The influence of the suction in the material on the thermal susceptibility is important since the suction that develops in the pavement is related to the environment. In situ measurements of the suction below newly constructed pavements in west Texas have verified this environmental relationship and shown that the base course is drier than the subgrade. The actual suction levels, however, were consistent with the predicted environmental levels (1). The major variable that affects the suction level in a given locale or material is the percentage of clay in the material. For the seven base course materials tested the suction versus freeze or residual coefficient relationship was

$$\log h = A + B \log w \tag{1}$$

where

h = suction,
w = gravimetric moisture content,
$A = 2.1995 + 0.3428$ (percent clay), $R^2 = 0.98$, and
$B = -[1.1480 + 0.2437$ (percent clay)], $R^2 = 0.72$

(The coefficients in these equations were derived for U.S. customary units.)

The specific surface area of a soil is the area available for the absorption of water. In a soil, the specific surface area of the clay fraction will be dominant since it is much the largest due to the small sizes of clay particles. Since adsorbed water has different properties than free water, the variations in specific surface area will be related to the thermal susceptibility, which is primarily a moisture-activated mechanism. The relations between the maximum freeze coefficient and the freeze coefficient of samples at optimum moisture contents to the specific surface area are shown in Figure 2. The regression relationships are as follows:

$$FC_{max} = -[2.8104 - 0.6776 \log(SSA)]^{-20.71}, \quad R^2 = 0.98 \tag{2}$$

$$FC_{optimum} = -[-0.6031 + 0.4298 \log(SSA)]^{-5.38} + 2.58 \times 10^{-4}, \quad R^2 = 0.97 \tag{3}$$

for modified AASHTO, and

$$FC_{max} = -[5551.1 - 2714.47 \log(SSA)]^{-1.493}, \quad R^2 = 0.91 \tag{4}$$

$$FC_{optimum} = -[-0.4098 + 0.2748 \log(SSA)]^{3.862} + 2.03 \times 10^{-4}, \quad R^2 = 0.98 \tag{5}$$

for Harvard miniature (SSA is the specific surface area).

Publication of this paper sponsored by Committee on Strength and Deformation Characteristics of Pavement Sections.

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These relations indicate that materials having larger specific surface areas (more active clay minerals) will have larger freeze coefficients, which means that they will contract more at a given freezing temperature. These data also indicate that the mechanism of thermal susceptibility is controlled by the clay mineralogy of the material.

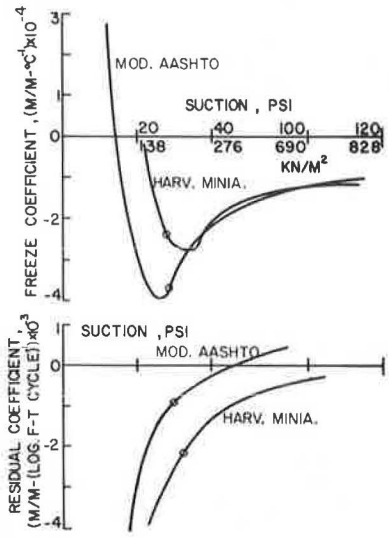

Figure 1. Freeze coefficient and residual coefficient as functions of the as-compacted suction: Position of optimum moisture content indicated.

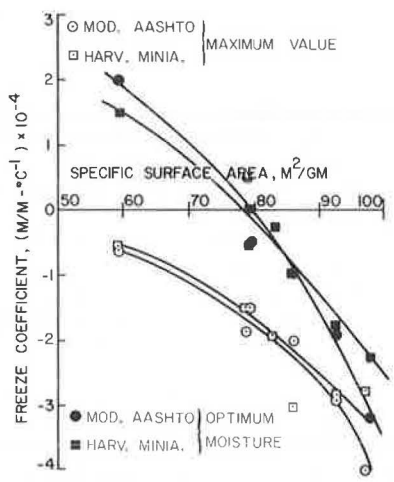

Figure 2. Maximum freeze coefficient and freeze coefficient at optimum moisture content as functions of specific surface area of clay minerals.

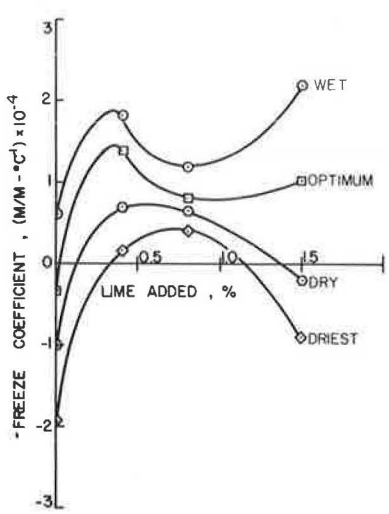

Figure 3. Change in freeze coefficient with variation in percent lime additive.

This relation of the suction and clay mineralogy with the freeze coefficient indicates the environmental relationship for this mechanism. There will be more activity in a drier area (higher suction) and less activity in a moister area (lower suction). The dry area will have activity near the maximum coefficient, and the moist area will have activity nearer to that which occurs at the optimum moisture content. This is less than the maximum and may even be expansive rather than contractive. Thus, the same material will behave in different ways in different climates.

PHYSICAL EFFECT ON PAVEMENT

The contraction of a base course during freezing conditions is similar to the contraction of an asphalt concrete during a temperature drop. The coefficient of contraction of the base course is much greater than that of the asphalt and its tensile strength is much less. This combination allows transverse cracks to first form in the base course and then be propagated through the asphalt in a manner similar to reflection cracking in overlays (3).

Transverse cracking from thermal susceptibility is much more severe than low temperature cracking of asphalt. Freeze-thaw cycling of the base course will lower its structural integrity and make it more susceptible to moisture damage when the crack has propagated, and traffic will deteriorate the pavement much more rapidly than if the asphalt had cracked from a low temperature.

STABILIZATION

These data show the mechanism of thermal susceptibility to be a clay surface and moisture interaction problem. Stabilization could therefore be accomplished by using common additives, for example, lime or salts. Thus, these additives were investigated to determine their effect on the mechanism, not for an increase in strength properties. The results for lime and salt (KCl) are shown in Figures 3 and 4 respectively for a material having medium activity. The conditions expected to develop in west Texas (dry samples) show an initial stabilization for 0.5 to 1.0 percent of the additive, but above this percentage the lime increased the contraction, pos-

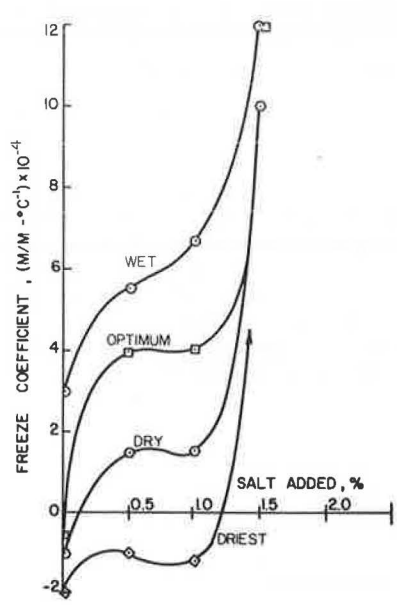

Figure 4. Change in freeze coefficient with variation in percent salt (KCl) additive.

sibly due to a pozzolanic reaction and increased cementation, and larger percentages of KCl caused expansion since the decrease in adsorbed water thickness provided more free water. The results of these tests indicate that stabilization will be very difficult to accomplish unless the percentages of additives can be accurately controlled.

CONCLUSIONS

Thermal susceptibility has a clay surface and moisture interaction mechanism that is triggered by a freeze in the base course. The magnitude of this activity can be predicted by study of the clay mineralogy involved. The deterioration caused by thermal susceptibility is much more damaging than low temperature cracking although the initial appearance is the same. Stabilization of the mechanism may be possible, but small variations in the amount of additive may cause more problems than initially existed.

ACKNOWLEDGMENTS

This work was performed for the Texas State Department of Highways and Public Transportation in cooperation with the Federal Highway Administration, U.S. Department of Transportation, under a cooperative research program through the Texas Transportation Institute, Texas A&M University. The contents of this report reflect the views of the author, who is responsible for the facts and the accuracy of the data presented. The contents do not necessarily reflect the official views or policies of the Federal Highway Administration. This report does not constitute a standard, specification, or regulation.

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